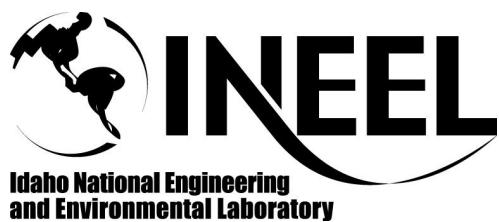


## **Engineering Design File**

PROJECT NO. 23350

## **Liner/Leachate Compatibility Study**



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Rev. 05

EDF No.: EDF-ER-278 EDF Rev. No.: 3 Project File No.: 23350

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5. Summary: This study evaluates the compatibility of the liner materials with the leachate generated by the waste disposed in the INEEL CERCLA Disposal Facility. The liner system is composed of both natural and synthetic materials including compacted clay, geosynthetic clay liner, high-density polyethylene, and polypropylene products. This study will determine whether these materials are compatible with the leachate, based on experience at similar landfills and published literature. Appendices F and G have been added to include constituent analysis additions.				
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Building/Type	<u>                  </u>	SSC ID	<u>                  </u> Site Area <u>                  </u>
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## **ABSTRACT**

This study evaluates the compatibility of the liner materials with the leachate generated by the waste disposed in the INEEL CERCLA Disposal Facility. The liner system is composed of both natural and synthetic materials including compacted clay, geosynthetic clay liner, high-density polyethylene, and polypropylene products. This study will determine whether these materials are compatible with the leachate, based on experience at similar landfills and published literature.

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## **ACRONYMS**

ASTM	American Society for Testing and Material
CCL	compacted clay liner
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CETCO	Colloid Environmental Technologies Company American
EDF	engineering design file
EPA	Environmental Protection Agency
GCL	geosynthetic clay liner
HDPE	high-density polyethylene
ICDF	INEEL CERCLA Disposal Facility
INEEL	Idaho National Engineering and Environmental Laboratory
LERF	Liquid Effluent Retention Facility
PCB	polychlorinated biphenyl
RCRA	Resource Conservation and Recovery Act
SBL	soil bentonite liner
TCE	trichloroethylene
TSCA	Toxic Substances Control Act
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WAC	Waste Acceptance Criteria

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# Liner/Leachate Compatibility Study

## 1. INTRODUCTION

### 1.1 Purpose

The purpose of this study is to demonstrate that the liner materials proposed for the INEEL CERCLA Disposal Facility (ICDF) landfill and evaporation pond are chemically compatible with the leachate. Certain materials deteriorate over time when exposed to chemicals that may be contained in hazardous leachate. It is important to anticipate the type and quality of the leachate that the landfill will generate and select compatible liner materials. Data collected from other similar low-level radioactive mixed waste and hazardous waste sites was used to determine the allowable concentration of leachate constituents that could be in contact with the ICDF landfill and evaporation pond liner components.

### 1.2 ICDF Liner System

The ICDF landfill and evaporation pond liners are a double composite system compliant with the substantive requirements of the Resource Conservation and Recovery Act (RCRA) Subtitle C and the Toxic Substances Control Act (TSCA) polychlorinated biphenyl (PCB) landfill and surface impoundment design, consisting of leachate collection/detection systems, a 3-ft-thick soil bentonite liner (SBL) (landfill only), and flexible membrane liners. The specific liner materials are listed below:

- High-density polyethylene (HDPE) geomembranes
- Geosynthetic clay liner (GCL) consisting of a thin layer of bentonite sandwiched between two synthetic geotextiles
- Geocomposite consisting of a HDPE geonet and geotextile
- Compacted clay soil with a bentonite admix (soil bentonite layer [SBL]) to decrease permeability.

The evaporation pond liner also includes an additional sacrificial geomembrane for UV protection.

In general, the liner system consists of two types of materials. The geomembranes, geotextiles, and geonets are manufactured from polymeric materials made from synthetic polymers. HDPE products have a high crystallinity that increases the chemical resistance of the polymer. The second type of material is soil comprised mainly of clay-sized particles, also crystalline in nature. As part of this study, no information was found with respect to the degradation of the geotextile materials. It was determined that even if the geotextile materials used in the liner system degraded, that it would not negatively impact the containment qualities of the landfill. Therefore, the degradation of geotextile was not considered as part of this study.

### 1.3 Mechanisms of Liner System Deterioration

Specific mechanisms of deterioration of the liner system components that might be encountered based on the waste inventory are chemical, radioactive, and oxidation degradation. Degradation involves a change in the physical properties of the liner material that could increase the permeability of the material or reduce the material's strength or ductility.

Polymeric chain scission or bond breaking within the polymer structure of HDPE results in degradation. Chemical degradation for HDPE products is a concern for leachates containing high concentrations of organic solvents or other highly reactive chemicals. High radiation doses also have the potential to cause chain scission in polymers. Oxidation occurs when free radicals and oxygen are present and results in chain scission. Oxidation processes are slowed considerably in liquid environments and antioxidant formulations are added to most HDPE products (Koerner 1998). Oxidation is also significantly reduced when the liner system is buried. As discussed herein, these processes are not expected to occur based on the ICDF leachate quality.

HDPE geomembranes can deteriorate from contact with certain leachates, resulting in a decrease of elongation at failure, an increase in modulus of elasticity, a decrease in the stress at failure, and a loss of ductility. Similarly, the permeability of a SBL and GCL can increase or decrease due to certain constituents in the leachate. This study is intended to establish individual leachate constituent concentration limits that will not adversely impact the liner system components. A summary of the properties for the HDPE, SBL, and GCL liner materials and the effects that could result from exposure to an aggressive leachate are summarized in Table 1. Notably, aggressive leachate in the ICDF landfill or waste liquid in the evaporation pond are not anticipated during their service life.

Table 1. Potential effects of aggressive leachate on liner materials.

Liner Material	Property	Typical Value	Possible Effect of Leachate
60 mil Textured HDPE	Thickness	> 60 mils	Decrease
	Melt Index	< 1.0 g/10 min	Increase or Decrease
	Strength at yield	> 120 lb/in.	Increase or Decrease
	Strength at break	> 75 lb/in.	Increase or Decrease
	Elongation at yield	> 12%	Increase or Decrease
	Elongation at break	> 100%	Increase or Decrease
	Tear Resistance	> 42 lb	Increase or Decrease
	Puncture Resistance	> 80 lb	Increase or Decrease
	Environmental Stress Crack	> 200 hours	Increase or Decrease
SBL	Permeability	$< 10^{-7}$ cm/sec	Increase or Decrease
GCL	Permeability	$< 10^{-7}$ cm/sec	Increase or Decrease

Sodium bentonite is the primary clay mineral in SBLs and GCLs that results in a low permeability and high swell potential. Exposure of sodium bentonite to liquids containing concentrated salts (such as brines), or divalent cation concentrations (such as Ca++ and Mg++), reduces the swelling potential and increases its permeability. Concentrated organic solutions (such as hydrocarbons) and strong acids and bases can break down the soil, which also increases permeability. The physical mechanism that causes these changes is a reduction of the thickness or absorption capacity of the diffuse double layer of water molecules surrounding the clay minerals. This results in an effective decrease in the volume of the clay since the water molecules are not attracted to the clay particles.

## 1.4 ICDF Leachate Concentrations

Soluble contaminants leached from the waste will come in contact with the landfill and evaporation pond bottom liner system during the operation period (15 years) and minimum post closure period (30 years). The natural soil bentonite liner system may be in contact with soluble contaminants as long as

contaminants are present in the landfill. The synthetic liner system components may be in contact with soluble contaminants until they naturally degrade or become ineffective. Leachate is generated from water added to the waste for dust control and compaction purposes. Natural precipitation events also contribute to leachate production. In reality, as the landfill nears the end of its operational life, concentrations of contaminants will decrease with time as the leachable waste mass is reduced. During the post-closure period, a robust landfill cover will significantly reduce infiltration, and the corresponding volume of leachate.

An inventory of constituents and associated site-specific concentrations anticipated in the waste are published in the INEEL CERCLA Disposal Facility Design Inventory (EDF-ER-264). The expected chemical make-up of the leachate was determined based on modeling described in the leachate/contaminant reduction time study (EDF-ER-274).

Two hydrogeologic models were used to simulate leachate generation during the operational period (15 years) and post-closure period (30 years) of the ICDF landfill and evaporation pond. The post-closure period includes the waste-filled landfill having a cover to reduce infiltration and the generation of leachate. The models applied partitioning coefficients to the waste design inventory mass to determine a liquid concentration for each constituent, and resulting leachate concentration.

In addition to the hydrogeologic models, a geochemical evaluation was performed for the operational period to evaluate natural geochemical reactions that could potentially generate constituents harmful to the liner system materials in the landfill or evaporation pond other than by the soluble waste constituents alone. It also was used to determine the general composition of the leachate including pH. The geochemical evaluation consisted of determining the chemistry make-up of the leachate based on the constituents in the waste soil and the geochemical reactions between the atmospheric gases (i.e., O<sub>2</sub>, CO<sub>2</sub>, etc.), infiltrating water, and natural occurring minerals in the soil.

The maximum and average leachate concentrations determined from the operational 15-year and post-closure 30-year hydrogeologic models were compared to determine the worst-case leachate concentrations due to the contaminants in the waste soil. Based on the comparison, the highest concentration of contaminates would occur during the operational period since contaminant transport tends to be dominated by drainage and diffusion, driven by the infiltration rate, which is expected to be small once the landfill is covered (EDF-ER-279).

Based on the geochemistry evaluation, the modeled leachate composition will be a brackish water with a pH of 8.0 (EDF-ER-274). Some of the constituents in the leachate had higher concentrations than determined by the hydrogeologic model due to the added effects of geochemical reactions. These mainly included sodium and sulfate having concentrations of approximately 8,000 and 20,000 mg/L, respectively. Brackish solutions containing high-concentration divalent cation concentrations such as calcium and magnesium can increase the permeability of the SBL and GCL liner materials as discussed in Section 1.3. The predicted divalent cation (calcium, magnesium, manganese, and barium) total concentration is approximately 400 mg/L. Higher concentrations are predicted from the 15-year hydrogeologic model of approximately 4,000 mg/L due to more conservative assumptions than the geochemical model. In either case, the divalent cation concentration is less than the maximum allowable concentration of 35,000 mg/L for the SBL and GCL described in Section 3.

Based on the 15-year hydrogeologic model, the maximum leachate concentration occurs during the first year of operation. The maximum and average concentrations for organics, inorganics, and radionuclides are provided in Table 2. These concentrations are considered conservative since they were determined assuming that the entire landfill is filled with waste instantaneously and has a constant moisture content of 6% by dry weight for all 15 years of operation.

Table 2. Maximum and average concentrations of leachate constituents by chemical category.

Chemical Category	Maximum Concentration	Average Concentration
Organics	70 mg/L	10 mg/L
Inorganics	18,400 mg/L	17,100 mg/L
Radionuclides	1 mg/L (0.00002 Ci/l)	1 mg/L (0.00001 Ci/l)

The resulting constituents determined from the leachate/contaminant reduction time study are provided in Appendix A. The organic constituents and expected concentrations are provided in Table A-1. The inorganic constituents and expected concentrations are provided in Table A-2. The expected radionuclides and activity concentrations are provided in Table A-3.

## 1.5 Absorbed Dose In Geomembrane

Studies performed on polymer materials like HDPE show that their properties begin to change after absorbing ionizing radiation between 1,000,000 to 10,000,000 rads (Koerner et al. 1990). The HDPE geomembrane lining the bottom of the landfill and evaporation pond will absorb ionizing radiation energy from the leachate generated in the landfill and combination of leachate and other waste liquids in the evaporation pond. Energy will be absorbed during the operational life of the landfill and evaporation pond as long as there are liquids with ionizing radionuclides in contact with the geomembranes.

The absorbed dose in the geomembrane was determined by multiplying the dose rate by an absorption duration. Conservatively, the absorption duration was assumed that the leachate was in contact continuously with the liner for the entire 15-year landfill operational life. In reality, leachate will be in contact with the landfill geomembrane intermittently depending on climatological and waste moisture content conditions. The absorption duration in the evaporation pond will be shortlived, due to evaporation and dilution from make-up water.

A design absorption rate was calculated for each of the radionuclides listed in Appendix A, Table A-3. Exceptions included Krypton (Kr-85 and Kr-81), which is a gaseous element, and radionuclides that are not in the leachate. The design absorption rate is dependent upon the physical properties of the absorbing material and how the energy from the source is deposited into the material. The physical properties of the HDPE geomembrane needed to determine the absorption rate are provided in Table 3.

Table 3. Physical properties of geomembranes.

Parameter	Value	Units
HDPE density	0.94	g/cm <sup>3</sup>
Geomembrane thickness	1.5	mm
Unit surface area	1	cm <sup>2</sup>

The amount of energy was based on the depth of leachate on the landfill liner and depth of liquids in the evaporation pond. The maximum depth of leachate was estimated as 4 cm across the floor of the landfill, assuming both Cell 1 and Cell 2 are in operation (EDF-ER-269). In the sump area of the landfill, the maximum leachate head would be approximately 30.5 cm. If the volume of leachate 4 cm deep over the area of the landfill (Cell 1 and Cell 2) was placed in the evaporation pond, the depth of leachate in the evaporation pond would be approximately 36 cm. Using these depths, the activity concentration, and the geomembrane proprieties, the design absorption rate was computed for each radionuclide. The

computation is provided in Appendix B. The design absorption rates are listed in Table A-4, provided in Appendix A.

The design absorbed dose to the geomembrane is approximately 0.09 and 0.8 rads per hour, for the landfill and evaporation pond, respectively. Assuming the leachate concentration and composition remains constant, the total doses over the 15-year operation life are conservatively estimated to be 12,000 and 100,000 rads for the landfill and evaporation pond, respectively. The total dose for the landfill for 1,000 years is estimated to be 800,000 rads. This assumes that all the energy from the leachate will be absorbed in the geomembranes. In reality, only small fractions of alpha and beta particles will penetrate the geomembrane material. Notably, the upper sacrificial geomembrane lining the evaporation ponds will absorb the majority of the ionizing radiation with little dose to the underlying primary geomembrane. Based on radiation absorbed dose, the mechanical properties of the HDPE liner are not expected to be degraded below acceptable levels.

## **2. EXISTING STUDIES OF LINER/LEACHATE COMPATIBILITY**

### **2.1 EPA Method 9090**

In 1992, EPA published Method 9090, ‘Compatibility Tests for Wastes and Membrane Liners,’ to set the standard that liners must meet to be protective of human health and the environment. This test has been used throughout the industry to demonstrate that liners are compatible with numerous leachate compositions from municipal and hazardous waste landfills, and surface impoundments. The results of these studies have been documented and are readily available. The manufacturers of the liners now supply limitations of the products based on these tests. The results are commonly accepted as reliable and complete. Since the ICDF leachate contains no unusual or excessive constituents, the industry results for these liners is sufficient to demonstrate compatibility.

The compatibility of GCL and SBL materials are usually demonstrated by permeating the material with leachate to determine its permeability. Method 9090 consists of immersing small sample specimens of a liner material in leachate and periodically measuring changes in the physical properties. The specimens are removed after 30, 60, 90, and 120 days, then tested to determine changes to the physical dimensions and mechanical properties. Acceptance criteria for defining compatibility tend to vary. Compatibility has been defined as geomembrane properties remaining above the minimum suggested property value or an allowable small percentage of change in properties (e.g., less than 15%) to maintain the integrity of the liner.

GCL and SBL are tested for compatibility by permeating the material with a leachate solution to determine effects on the hydraulic performance of the material. Typically, solutions with high concentrations of contaminants or pure products are allowed to permeate a sample under confining pressure to determine the saturated permeability of the material using ASTM methods such as ASTM D5084. A saturated permeability exceeding  $1 \times 10^{-7}$  cm/sec would indicate incompatibility.

The HDPE geomembrane and GCL materials planned for the ICDF are considered to be the most chemically inert liner materials commercially available for waste disposal facilities. Numerous studies using EPA Method 9090 and permeability tests, among other testing procedures, have been performed for waste disposal facilities and in the laboratory providing a good understanding of the compatibility behavior of these liner materials.

## 2.2 Published Studies

### 2.2.1 Comparison with Other Geomembrane 9090 Compatibility Studies

Relevant compatibility studies have been performed at DOE's Hanford facility near Richland, Washington. These projects include the Liquid Effluent Retention Facility (LERF), W-025 landfill, and the Grout Facility. Other relevant studies include the Kettleman Hills landfill located in northern California. The results of these published studies indicate that a HDPE geomembrane will function well as a liner beneath the landfill waste or liquid waste in the evaporation pond. The published geomembrane compatibility studies for the Hanford facility are listed in Section 6 Bibliography of this report.

A comparison between the anticipated ICDF landfill leachate and that used in compatibility tests for other facilities is summarized in Table 4.

Table 4. EPA test method 9090 compatibility studies comparison.

Compatibility Study <sup>a</sup>	Type of Material Tested	General Composition of Leachate	9090 <sup>b</sup> Test Concentrations or Radiation Exposure that Demonstrated Compatibility in Each Study	ICDF <sup>c</sup> Leachate Concentration/ Absorbed Radiation
Hanford LERF	60-mil smooth HDPE from four manufacturers	Organics	16.25 mg/L	70 mg/L
Hanford W-025 Landfill	60-mil smooth HDPE	Inorganics Organic Leachate and Radiation Exposure	204,210 mg/L 50,000 rads	18,400 <sup>g</sup> mg/L 12,000 rads (landfill) 100,000 rads (evaporation pond)
Hanford Grout Facility	60-mil smooth HDPE	pH Inorganics Organic Leachate and Radiation <sup>e</sup> Exposure Organic Leachate and Radiation <sup>f</sup> Exposure	9.2 368,336 mg/L 37,000,000 rads 16,000,000 rads	8.0 18,400 mg/L 12,000 rads (landfill) 100,000 rads (evaporation pond)
Kettleman Hills Landfills	60-mil smooth HDPE	pH Organics Inorganics pH	>14 93,040 mg/L 250,000 mg/L >12	8.0 70 mg/L 18,400 mg/L 8.0
Unidentified Landfill Study	Textured HDPE	Organics	154 mg/L	70 mg/L

a. Detailed compatibility test information is provided in *Evaluation of Liner/Leachate Chemical Compatibility for the Environmental Restoration Disposal Facility report* (USACE 1995).

b. EPA Test Method 9090 "Compatibility Test for Wastes and Membrane Liners" (EPA 1992).

Values reported represent values at which the test was run, showing no unacceptable effects. They do not represent an allowable limit.

Values based on the "Leachate/Contaminant Reduction Time Study" (EDF-ER-274).

c. A slight reduction in strength and elasticity of the HDPE liner occurred at the highest doses used in the testing.

f. No measurable changes in the HDPE liner material properties were observed after the testing.

g. Reported as total inorganics.

HDPE is chemically resistant to inorganic salt solutions and can be incompatible with some organic solutions at high concentrations (i.e., pure products). Actual compatibility tests from other landfills show that HDPE is chemically resistant to much higher concentrations of organics in the leachate than what is expected in the ICDF leachate. The organic concentration in the Kettlemen Hills Landfill leachate is almost four orders of magnitude higher than what is expected in the ICDF landfill leachate. The use of general categories of chemicals rather than individual constituents has been accepted by the EPA for the Environmental Restoration Disposal Facility at Hanford and provide a worst-case scenario due to possible synergistic effects of mixed compounds.

The EPA Method 9090 tests performed on HDPE geomembrane liner planned for the Grout Facility included high temperatures and doses of large amounts of radiation. The leachate solution temperature was increased to 194°F, which is significantly above the standard test temperatures of 73° and 122°F required in Method 9090. Additionally, the samples were irradiated at doses up to 37,000,000 rads prior to the testing, significantly decreasing the strength and elasticity (i.e., greater than 25%) of the geomembrane specimens (USACE 1995). Geomembrane samples tested for the W-025 facility did not produce measurable changes in the HDPE liner properties when irradiated for 120 days with a total dose of 50,000 rads. HDPE geomembranes are manufactured with additives to improve ductility and durability such as carbon black and antioxidants. The literature also indicates that these additives allow higher doses than standard HDPE material alone (Kircher and Bowman 1964). The literature indicates that thin films (i.e., 0.002 in.) of different types of HDPE material alone can become brittle when irradiated at doses between 4,400,000 and 78,000,000 rads. Studies performed using polymer materials show that properties typically begin to change at a total radiation dose of between 1,000,000 and 10,000,000 rads (Koerner et al. 1990).

The landfill and evaporation pond HDPE geomembrane liners are expected to receive a dose from the leachate of 12,000 and 100,000 rads, respectively. This is a conservatively high dose since it assumes that concentrations of radionuclides are constant in the leachate over the 15-year operational life of the landfill. Even though conservatively high, the total dose is below the dose found in other studies (i.e., 1,000,000 rads) that may affect the properties of the geomembrane.

## 2.2.2 Geosynthetic Clay and Soil Bentonite Liners

Based on review of the published studies listed in Section 6 (Bibliography), SBL and GCL perform well unless exposed to high concentrations of divalent cations, very acidic or basic solutions, or solutions with a low dielectric constant (such as gasoline). The leachate expected at the ICDF will have a pH of 8, slightly above neutral. The studies further demonstrate that, when confined, as is the case in the ICDF landfill, or pre-hydrated, SBLs and GCLs will perform well when exposed to high divalent cation concentrations.

Several studies were found that evaluated the impact of SBL permeability with various organic and inorganic materials. The majority of them used very concentrated compounds, which is not the typical composition of landfill leachates and when compared with ICDF leachate exceeded concentrations by as much as an order of magnitude. One study was found that addressed the issue of when leachate constituent concentrations impact SBL permeability. For this study, four different types of organic compounds were used as permeants. They included methanol, acetic acid, heptane, and trichloroethylene (TCE). The results indicate that soil permeability was not affected by methanol until a concentration of 80% by volume was used. The acetic acid actually reduced the soil permeability due to dissolution and reprecipitation of the soil. Heptane and TCE had no effect on permeability when used up to their solubility limit in water. However, when used in pure form, they increased the soil permeability significantly (250 to 1,000 times). In addition to the concentration of the permeant used, changes in

hydraulic permeability are also governed by the mineralogy of the soil (Borders 1986). Although only low concentrations of TCE are predicted in the ICDF leachate, the study demonstrates that high concentrations of organic constituents are required to affect permeability.

No studies were identified that considered the long-term effects of radiation on the physical properties of the SBL or GCL materials. Since long-term studies cannot be conducted, conservative radiation limitations have been employed. Low-permeability soils have been used at multiple DOE facilities containing radioactive waste. The only potential adverse reaction that could occur with the SBL or GCL would be high heat that could dry out these materials, however, it is anticipated that the radioactive material placed in the ICDF will not generate any thermal gradients across the liner system.

The concentration of organic material is expected to be approximately 70 mg/L. This is significantly below the concentration of a highly concentrated solution so it will not increase the permeability of the SBL and GCL. The amount of radioactivity will be low in the ICDF landfill waste and will not generate a significant amount of heat that can desiccate the compacted clay. Additionally, the operations layer will provide a 3-ft buffer between the liner system and waste.

## 2.3 Manufacturers' Data

### 2.3.1 HDPE Geomembrane

The manufacturers of the geosynthetic products proposed for the ICDF landfill have published maximum allowable concentrations of various chemical compounds that can contact the HDPE geomembrane without adversely affecting its performance. The most recent recommended maximum concentrations of chemicals were obtained from the manufacturer. A list of the manufacturers' maximum allowable concentrations for specific leachate constituents on HDPE material is provided in Appendix C. In addition, the effects of radiation exposure with respect to the geomembrane physical properties are also presented.

### 2.3.2 Geosynthetic Clay and SBLs

The GCL underlying the geomembrane in the ICDF landfill and evaporation pond liner consists of processed sodium bentonite clay sandwiched between two geotextile fabrics. The SBL underlying the geosynthetic liners also consists of 5% by weight of processed bentonite amendment. Sodium bentonite is an ore comprised mainly of the montmorillonite clay mineral with broad, flat, negatively charged platelets that attract water hydrating the bentonite. The swelling provides the ability to seal around penetrations, giving the GCL its self-healing properties. A GCL product with Volclay® type sodium bentonite manufactured by CETCO will be installed in the landfill and evaporation pond.

The GCL manufacturer allows the use of GCL with few restrictions on maximum chemical concentrations. The manufacturer does recommend that treated bentonite should be used when directly exposed to liquids with high concentration of salts (divalent cations) such as in seawater (CETCO 2001). The concentration of salts in typical seawater is on the order of 35,000 mg/L (USGS 1989). The ICDF total inorganic leachate concentration is on the order of 17,000 mg/L, approximately 2 times lower than that of seawater. The same compatibility limitation is found in the literature as described in Section 2.1.2. The bentonite added to the soil for the bentonite liner will have the same limitation, however, to a lesser extend since only a small percentage (i.e., 5%) is comprised of bentonite. Based on this assessment, the exposed salts in the brackish leachate will be compatible with the GCL and SBL underlying the geomembrane. Notably, this assumes that the overlying HDPE geomembranes must leak before leachate can come in contact with the GCL or SBL.

### 3. WASTE ACCEPTANCE CRITERIA

#### 3.1 Landfill

Individual constituents in the ICDF landfill design inventory were evaluated to determine maximum allowable ICDF landfill waste concentrations, that if placed in the landfill would generate leachate compatible with the liner system. Many of the individual design inventory constituents have not been included in the composition of leachate used for published compatibility studies. However, the constituents used in the published studies are in similar chemical groups as the constituents in the ICDF design inventory and therefore, would react similarly with the liner materials. Moreover, the use of general chemical categories rather than individual constituents provide a worst-case scenario due to possible synergistic effects of mixed compounds.

Table 5 provides the recommended maximum concentration of chemical categories that, if in the landfill leachate, may be incompatible with the polymeric or earthen material comprised of the ICDF landfill and evaporation pond liner systems. These limits are based on review of the published liner compatibility studies and manufacturers' recommendations. The maximum allowable concentration for HDPE geomembrane, GCL, and SBL were compared to determine the highest acceptable value. The lowest of all three values was selected as the suggested maximum concentration. The concentrations based on the design inventory of waste constituents are also provided in Table 5. Where available, the recommended maximum allowable concentration with regard to liner compatibility for individual constituents is provided in Tables D-1, D-2, and D-3 in Appendix D for specific organic, inorganic, and radionuclide constituents, respectively.

Table 5. Maximum allowable concentrations in leachate by chemical category.

Chemical Category	Compatible Concentration for HDPE	Compatible Concentration for GCL and Clay	Suggested ICDF Maximum Concentration or Value	Design Inventory Concentration Dose or Value
Organics	500,000 <sup>a</sup> mg/L	500,000 <sup>b</sup> mg/L	500,000 mg/L	70 mg/L
Acids and Bases	750,000 <sup>a</sup> mg/L	500,000 <sup>b</sup> mg/L	500,000 mg/L	0 <sup>d</sup> mg/L
Inorganic	500,000 <sup>a</sup> mg/L	500,000 <sup>b</sup> mg/L	500,000 mg/L	17,100 mg/L
Dissolved Salts	No Limit	35,000 mg/L	35,000 mg/L	8,000 mg/L <sup>c</sup>
Strong Oxidizers	1,000 mg/L	No limit	1,000 mg/L	0 <sup>d</sup> mg/L
Radionuclides	1,000,000 <sup>b</sup> rads	No limit	1,000,000 rads	12,000 rads (15 yr) 800,000 rads (1000 yr)
pH	0.5 - 13.0 <sup>a</sup>	0.5 - 13.0	0.5 - 13.0	8.0

a. Based on the manufacturers' maximum concentration of the list of constituents tested by the manufacturers. The manufacturers' recommendations are provided in Appendix C.

b. Based on reported literature values.

c. Based on the maximum sodium concentration determined in the Geochemical Evaluation.

d. Strong acids, bases, or oxidizing compounds were not reported in the design inventory.

The concentration and exposure limits in Table 5 provide Waste Acceptance Criteria (WAC) for chemical categories. These values can be used as a general guide to determine WAC if individual constituents in the leachate are lower than the limits provided in Appendix D.

The maximum allowable activity concentration of individual radionuclides was determined based on a maximum allowable dose of 1,000,000 rads. The calculated values are provided in Table C-3 in Appendix C. Based on radiation absorbed dose, the mechanical properties of the HDPE liner are not expected to be degraded below acceptable levels.

### **3.2 Evaporation Pond**

The evaporation pond liner system will be comprised of HDPE geomembrane and GCL similar to the landfill liner system underlying a sacrificial geomembrane. The evaporation pond will contain leachate from the landfill and waste liquids from other CERCLA investigations (i.e., well purge water) or remediation tasks. Organics and inorganics in the leachate compatible with the landfill liner will also be compatible with the evaporation pond liner materials since they will be comprised of the same material. Leachate in the evaporation pond from the landfill will also have less concentration of contaminants than when originally in the landfill due to added make-up water, and precipitation.

The maximum allowable concentration of an individual radionuclide and WAC design ratios for the evaporation pond liner is provided in Appendix E. The maximum concentration was developed in the same manner as the landfill maximum allowable concentration assuming a maximum absorption dose of 1,000,000 rads. The allowable concentrations are less than in the landfill due to a greater depth of liquid in the evaporation pond resulting in a higher dose rate.

Waste liquids from other sources in the evaporation pond should not exceed the maximum allowable concentrations of liquids by chemical category in Table 5. The recommended maximum allowable concentrations with regard to liner compatibility for individual constituents are provided in Table D-4 of Appendix D.

## **4. CONCLUSIONS**

An extensive literature review was performed to evaluate the compatibility of the ICDF landfill and evaporation pond liner materials with the expected leachate composition. Compatibility tests performed at similar sites have shown that HDPE geomembranes can be exposed to high doses of radiation without damage and are compatible with leachate from hazardous waste landfills. Liner manufacturers have also performed compatibility tests using numerous organic and inorganic chemicals, usually in a pure solution, to determine maximum allowable limits. Based on review of literature, the expected leachate concentrations will have no effect on the performance of the ICDF liner system based on the available literature.

The maximum recommended concentration of chemical categories was provided to supply the WACs regarding liner compatibility. General chemical categories rather than individual constituents provide a worst-case scenario due to possible synergistic effects of mixed compounds. However, to provide numerical WAC, individual constituents in the ICDF design inventory were evaluated to determine maximum allowable ICDF landfill waste soil concentrations with regard to liner compatibility. The maximum allowable ICDF landfill waste concentrations are provided in Appendix D.

Samples of 60-mil-thick HDPE geomembrane were irradiated with a total radiation dose of 16,000,000 and 37,000,000 rads for the Hanford Grout facility. The dose rate was 740,000 rads per hour for a total time of 50 hours. These doses showed decreases in the liner's break strength and break elongation due to radiation-induced cross-linking for the polymer chains, decreasing the plasticity of the liner. At the Hanford project W-025 landfill, the HDPE liner showed only a slight reduction in mechanical properties including tensile strength and elasticity after it was irradiated to 50,000 rads for

120 days while submerged in leachate. The literature indicates that the mechanical properties of polymeric materials begin to change at approximately 1,000,000 rads. The geomembrane can accommodate a slight reduction in its strength properties without creating defects that result in leaks since the actual properties are more robust than the design properties (i.e., thickness). Therefore, a maximum radiation dose of 1,000,000 rads for the landfill and evaporation pond liner system during their respective service life is recommended.

The manufacturer for the ICDF geomembrane recommends that leachate have a pH between 0.5 and 13 pH units. Recommended manufacturers' limits for strong oxidizers are 1,000 to 500,000 mg/L and metals, salts, and nutrients of 500,000 mg/L. The permeability of the bentonite used in the GCL and SBL may increase if permeated with leachate having a salt ion concentration. Therefore, a maximum inorganic salt concentration of 35,000 mg/L is recommended as a conservative upper limit. These limits are far above the concentrations expected in the leachate from the ICDF landfill and waste liquids in the evaporation pond. They will be used to determine the maximum allowable concentrations in the waste soil and liquids that if placed in the ICDF landfill or evaporation would not cause significant degradation of the liner system.

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## **Appendix A**

### **Expected Leachate Design Concentrations and Absorbed Radiation Dose**

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## Appendix A

### Expected Leachate Design Concentrations and Absorbed Radiation Dose

Table A-1. Predicted organic concentrations in leachate.

Constituent <sup>a</sup>	Maximum Leachate Concentration <sup>b</sup> (mg/L)	Average Leachate Concentration (mg/L)	Constituent <sup>a</sup>	Maximum Leachate Concentration <sup>b</sup> (mg/L)	Average Leachate Concentration (mg/L)
1,1,1-Trichloroethane	0.0609	0.0073	Acenaphthene	0.0399	0.0028
1,1,2,2-Tetrachloroethane	0.0002	0.0000	Acenaphthylene	0.3366	0.0230
1,1,2-Trichloroethane	0.0013	0.0002	Acetone	6.2674	0.3917
1,1-Dichloroethane	0.0105	0.0009	Acetonitrile	0.0002	0.0000
1,1-Dichloroethene	0.0004	0.0000	Acrolein	0.0001	0.0000
1,2,4-Trichlorobenzene	0.0113	0.0010	Acrylonitrile	0.0000	0.0000
1,2-Dichlorobenzene	0.0734	0.0046	Anthracene	0.0083	0.0013
1,2-Dichloroethane	0.0001	0.0000	Aramite	0.0000	0.0000
1,2-Dichloroethene (total)	0.0003	0.0000	Aroclor-1016	0.0000	0.0000
1,3-Dichlorobenzene	0.0071	0.0006	Aroclor-1254	0.0002	0.0000
1,4-Dichlorobenzene	5.1303	0.4578	Aroclor-1260	0.0087	0.0005
1,4-Dioxane	0.0000	0.0000	Aroclor-1268	0.2891	0.0181
2,4,5-Trichlorophenol	0.0441	0.0114	Benzene	1.3491	0.1685
2,4,6-Trichlorophenol	0.0427	0.0109	Benzidine	0.0000	0.0000
2,4-Dichlorophenol	0.0371	0.0023	Benzo(a)anthracene	0.0001	0.0000
2,4-Dimethylphenol	0.3041	0.0190	Benzo(a)pyrene	0.0000	0.0000
2,4-Dinitrophenol	0.1705	0.0173	Benzo(b)fluoranthene	0.0000	0.0000
2,4-Dinitrotoluene	0.0488	0.0041	Benzo(g,h,i)perylene	0.0000	0.0000

Table A-1. (continued).

Constituent <sup>a</sup>	Maximum Leachate Concentration <sup>b</sup> (mg/L)	Average Leachate Concentration (mg/L)	Constituent <sup>a</sup>	Maximum Leachate Concentration <sup>b</sup> (mg/L)	Average Leachate Concentration (mg/L)
2,6-Dinitrotoluene	0.2903	0.0242	Benzo(k)fluoranthene	0.3024	0.1623
2-Butanone	0.0063	0.0004	Benzoic acid	0.1162	0.0073
2-Chloronaphthalene	0.0108	0.0007	Bis(2-Chloroethoxy)methane	0.0455	0.0444
2-Chlorophenol	0.1867	0.0208	bis(2-Chloroethyl)ether	0.0535	0.0048
2-Hexanone	0.0001	0.0001	bis(2-Chloroisopropyl)ether	0.0000	0.0000
2-Methylnaphthalene	1.7772	1.7403	bis(2-Ethylhexyl)phthalate	0.5714	0.0497
2-Methylphenol	0.2014	0.0126	Butane,1,1,3,4-Tetrachloro-	0.0001	0.0000
2-Nitroaniline	0.1728	0.1663	Butylbenzylphthalate	0.0080	0.0005
2-Nitrophenol	0.0098	0.0006	Carbazole	0.1856	0.1793
3,3'-Dichlorobenzidine	0.1896	0.0168	Carbon Disulfide	0.0734	0.0046
3-Methyl Butanal	0.0022	0.0021	Chlorobenzene	0.0679	0.0062
3-Nitroaniline	0.0165	0.0165	Chloroethane	0.0000	0.0000
4,6-Dinitro-2-methylphenol	0.0010	0.0001	Chloromethane	0.0000	0.0000
4-Bromophenyl-phenylether	0.0615	0.0595	Chrysene	4.4199	1.4812
4-Chloro-3-methylphenol	0.0810	0.0789	Decane, 3,4-Dimethyl	0.0004	0.0004
4-Chloroaniline	0.0052	0.0052	Diacetone alcohol	0.0005	0.0000
4-Chlorophenyl-phenylether	0.0288	0.0284	Dibenz(a,h)anthracene	0.0006	0.0002
4-Methyl-2-Pentanone	0.1131	0.0071	Dibenzofuran	0.4156	0.0260
4-Methylphenol	0.3766	0.0235	Diethylphthalate	0.1897	0.0120
4-Nitroaniline	0.1728	0.1663	Dimethyl Disulfide	0.0127	0.0124
4-Nitrophenol	0.0029	0.0002	Dimethylphthalate	0.0001	0.0000
Di-n-butylphthalate	0.0000	0.0000	N-Nitroso-di-n-propylamine	0.0035	0.0003
Di-n-octylphthalate	0.4370	0.0370	N-Nitrosodiphenylamine	0.1896	0.0119
Eicosane	0.0472	0.0029	Octane,2,3,7-Trimethyl	0.0027	0.0024

Table A-1. (continued).

Constituent <sup>a</sup>	Maximum Leachate Concentration <sup>b</sup> (mg/L)	Average Leachate Concentration (mg/L)	Constituent <sup>a</sup>	Maximum Leachate Concentration <sup>b</sup> (mg/L)	Average Leachate Concentration (mg/L)
Ethyl cyanide	0.0000	0.0000	o-Toluenesulfonamide	0.0033	0.0033
Ethylbenzene	0.0705	0.0050	Pentachlorophenol	0.0046	0.0010
Famphur	0.0000	0.0000	Phenanthrene	8.8500	0.8023
Fluoranthene	0.0221	0.0039	Phenol	0.1370	0.0086
Fluorene	3.0594	0.2043	Phenol,2,6-Bis(1,1-Dimethyl)	0.0674	0.0042
Heptadecane, 2,6,10,15-Tetra	0.0000	0.0000	p-Toluenesulfonamide	0.0000	0.0000
Hexachlorobenzene	0.0001	0.0000	Pyrene	3.2501	1.4592
Hexachlorobutadiene	0.0000	0.0000	RDX	0.0000	0.0000
Hexachlorocyclopentadiene	0.0025	0.0002	Styrene	0.0000	0.0000
Hexachloroethane	0.0000	0.0000	Tetrachloroethene	0.0235	0.0039
Indeno(1,2,3-cd)pyrene	0.1585	0.0524	Toluene	16.3666	1.0229
Isobutyl alcohol	0.0001	0.0000	Tributylphosphate	1.2292	0.1704
Isophorone	0.1829	0.0114	Trichloroethene	1.1526	0.3027
Isopropyl Alcohol/2-propanol	0.0000	0.0000	Trinitrotoluene	0.0000	0.0000
Kepone	0.2511	0.0704	Undecane,4,6-Dimethyl-	0.0003	0.0003
Mesityl oxide	1.2939	0.0809	Xylene (ortho)	0.0071	0.0006
Methyl Acetate	0.0057	0.0053	Xylene (total)	6.2805	0.5293
Methylene Chloride	0.0165	0.0010	Total Organics	69.5426	10.4515
Naphthalene	1.9193	0.1398			
Nitrobenzene	0.0948	0.0082			

a. Constituents based on the design Inventory (EDF-ER-264)

b. Peak and average concentrations during the 15 year active life of the landfill assuming the entire mass is placed in the landfill (EDF-ER-274)

Table A-2. Expected peak inorganic concentrations in leachate.

Constituent <sup>a</sup>	Maximum Leachate Concentration (mg/L) <sup>b</sup>	Average Leachate Concentration (mg/L) <sup>b</sup>
Aluminum	28.3029	28.3022
Antimony	0.1165	0.1164
Arsenic	1.8470	1.8434
Barium	3.5848	3.5843
Beryllium	0.0011	0.0011
Boron	36.4728	36.4292
Cadmium	0.5917	0.5911
Calcium	4035.0217	4030.1943
Chloride	31.1061	28.1653
Chromium	1.3691	1.3689
Cobalt	0.5999	0.5996
Copper	1.4906	1.4902
Cyanide	4.0932	3.8059
Dysprosium	0.2472	0.2472
Fluoride	64.4341	58.3424
Iron	46.5528	46.5516
Lead	0.5753	0.5753
Magnesium	883.9838	882.9262
Manganese	4.1300	4.1295
Mercury	49.7230	48.1710
Molybdenum	1.0117	1.0111
Nickel	0.1964	0.1964
Nitrate	65.4429	59.2558
Nitrate/Nitrite-N	3.6979	3.3483
Nitrite	0.1414	0.1281
Phosphorus	19.2492	19.2261
Potassium	74.8819	74.8518
Selenium	0.2084	0.2080
Silver	0.1092	0.1092
Sodium	2.7716	2.7714
Strontium	1.5094	1.5087
Sulfate	342.1180	309.7736
Sulfide	12641.8391	11446.6606
Terbium	2.3867	2.3866
Thallium	0.0037	0.0037
Vanadium	3.5063	3.5028
Ytterbium	0.8124	0.8123
Zinc	12.9486	12.9437
Zirconium	0.1151	0.1151
Total Inorganic Concentration	18367.1936	17116.2485

a. Constituents based on the design Inventory (2001 EDF-264)

b. Peak and average concentrations during the 15 year active life of the landfill assuming the entire mass is placed in the landfill (EDF-ER-274)

Table A-3. Expected peak rationuclides concentrations in leachate.

Constituent <sup>a</sup>	Maximum Leachate Concentration (pCi/L) <sup>b</sup>	Average Leachate Concentration (pCi/L) <sup>b</sup>	Constituent <sup>a</sup>	Maximum Leachate Concentration (pCi/L) <sup>b</sup>	Average Leachate Concentration (pCi/L) <sup>b</sup>
Ac225	1.1E-07	7.1E-09	Cm241	3.2E-81	2.0E-82
Ac227	4.5E-05	3.6E-05	Cm242	1.3E-17	1.1E-18
Ac228	3.4E-10	2.1E-11	Cm243	8.9E-07	7.4E-07
Ag106	0.0E+00	0.0E+00	Cm244	4.5E-04	3.4E-04
Ag108	4.1E-08	2.6E-09	Cm245	2.0E-08	2.0E-08
Ag108m	8.9E+00	8.5E+00	Cm246	4.5E-10	4.5E-10
Ag109m	5.5E-11	3.4E-12	Cm247	1.6E-16	1.6E-16
Ag110	5.7E-10	3.6E-11	Cm248	4.9E-17	4.9E-17
Ag110m	6.2E-08	6.0E-09	Cm250	1.4E-25	1.4E-25
Ag111	0.0E+00	0.0E+00	Co57	3.7E-01	3.8E-02
Am241	7.0E+01	6.9E+01	Co58	5.8E-15	3.8E-16
Am242	1.3E-04	8.3E-06	Co60	1.9E+04	8.6E+03
Am242m	1.3E-04	1.3E-04	Cr51	7.7E-53	4.8E-54
Am243	9.8E-04	9.8E-04	Cs132	0.0E+00	0.0E+00
Am245	0.0E+00	0.0E+00	Cs134	2.2E+01	4.9E+00
Am246	4.1E-25	2.5E-26	Cs135	7.2E-02	7.2E-02
At217	8.5E-04	5.3E-05	Cs136	0.0E+00	0.0E+00
Ba136m	0.0E+00	0.0E+00	Cs137	4.9E+04	4.1E+04
Ba137m	4.6E+05	2.9E+04	Er169	0.0E+00	0.0E+00
Ba140	0.0E+00	0.0E+00	Eu150	5.1E-08	3.2E-09
Be10	4.6E-06	4.6E-06	Eu152	2.8E+03	2.0E+03
Bi210	1.1E-05	6.8E-07	Eu154	2.4E+03	1.4E+03
Bi211	1.8E-04	1.1E-05	Eu155	5.2E+02	2.2E+02

Table A-3. (continued).

Constituent <sup>a</sup>	Maximum Leachate Concentration (pCi/L) <sup>b</sup>	Average Leachate Concentration (pCi/L) <sup>b</sup>	Constituent <sup>a</sup>	Maximum Leachate Concentration (pCi/L) <sup>b</sup>	Average Leachate Concentration (pCi/L) <sup>b</sup>
Bi212	5.5E-03	3.5E-04	Eu156	0.0E+00	0.0E+00
Bi213	0.0E+00	0.0E+00	Fe59	2.0E-34	1.3E-35
Bi214	5.6E-05	3.5E-06	Fr221	1.0E-07	6.4E-09
Bk249	5.4E-22	6.2E-23	Fr223	5.6E-07	3.5E-08
Bk250	1.9E-26	1.2E-27	Gd152	1.1E-13	1.1E-13
C14	9.1E-03	9.1E-03	Gd153	8.4E-11	8.1E-12
Cd109	8.1E-10	1.2E-10	H3	8.3E+05	5.2E+05
Cd113m	2.7E+02	1.9E+02	Hf181	1.7E-36	1.1E-37
Cd115m	7.0E-52	4.4E-53	Ho166m	1.1E-05	6.7E-07
Ce141	3.6E-71	2.3E-72	I129	2.2E+04	2.0E+04
Ce142	0.0E+00	0.0E+00	I131	0.0E+00	0.0E+00
Ce144	3.6E-03	3.8E-04	In114	4.8E-54	3.0E-55
Cf249	8.1E-16	8.0E-16	In114m	5.1E-54	3.2E-55
Cf250	4.1E-16	2.9E-16	In115	1.5E-11	1.5E-11
Cf251	1.9E-18	1.9E-18	In115m	0.0E+00	0.0E+00
Cf252	4.4E-20	1.2E-20	K40	1.3E+02	1.3E+02
Kr81 <sup>c</sup>	0.0E+00	8.0E-05	Po216	3.7E-03	2.3E-04
Kr85 <sup>c</sup>	0.0E+00	1.1E+07	Po218	3.7E-05	2.3E-06
La138	0.0E+00	0.0E+00	Pr143	0.0E+00	0.0E+00
La140	2.2E-105	1.4E-106	Pr144	7.4E-03	4.6E-04
Mn54	3.9E-07	4.3E-08	Pr144m	1.1E-04	6.6E-06
Nb92	6.3E-18	6.3E-18	Pu236	3.9E-05	1.1E-05
Nb93m	1.3E-01	9.5E-02	Pu237	8.6E-58	5.4E-59
Nb94	8.8E-05	8.8E-05	Pu238	1.7E+03	1.6E+03

Table A-3. (continued).

Constituent <sup>a</sup>	Maximum Leachate Concentration (pCi/L) <sup>b</sup>	Average Leachate Concentration (pCi/L) <sup>b</sup>	Constituent <sup>a</sup>	Maximum Leachate Concentration (pCi/L) <sup>b</sup>	Average Leachate Concentration (pCi/L) <sup>b</sup>
Nb95	4.8E-32	3.0E-33	Pu239	4.8E+01	4.8E+01
Nb95m	1.8E-34	1.1E-35	Pu240	1.1E+01	1.1E+01
Nd144	1.4E-09	1.4E-09	Pu241	4.6E+02	3.3E+02
Nd147	0.0E+00	0.0E+00	Pu242	1.7E-03	1.7E-03
Np235	8.4E-09	1.1E-09	Pu243	4.6E-15	2.9E-16
Np236	8.6E-06	8.6E-06	Pu244	1.8E-10	1.8E-10
Np237	8.0E+01	8.0E+01	Pu246	9.9E-25	6.2E-26
Np238	2.7E-05	1.7E-06	Ra222	1.2E-115	7.3E-117
Np239	4.1E-02	2.6E-03	Ra223	2.0E-04	1.3E-05
Np240	3.5E-12	2.2E-13	Ra224	5.5E-03	3.5E-04
Np240m	3.1E-09	2.0E-10	Ra225	5.1E-07	3.2E-08
Pa231	1.3E-04	1.3E-04	Ra226	4.7E+00	4.7E+00
Pa233	7.9E-02	4.9E-03	Ra228	1.5E-09	7.2E-10
Pa234	5.0E-06	3.1E-07	Rb86	0.0E+00	0.0E+00
Pa234m	3.1E-03	1.9E-04	Rb87	2.0E-04	2.0E-04
Pb209	4.8E-07	3.0E-08	Rh102	5.7E-04	1.6E-04
Pb210	1.1E-05	8.7E-06	Rh103m	5.4E-57	3.4E-58
Pb211	1.8E-04	1.1E-05	Rh106	2.2E-01	1.4E-02
Pb212	5.5E-03	3.5E-04	Rn218	2.1E-112	1.3E-113
Pb214	5.6E-05	3.5E-06	Rn219	3.4E-01	2.1E-02
Pd107	1.1E-01	1.1E-01	Rn220	9.2E+00	5.8E-01
Pm146	2.4E-02	1.1E-02	Rn222	1.0E-01	6.5E-03
Pm147	1.6E+03	4.2E+02	Ru103	3.6E-28	2.3E-29
Pm148	1.7E-58	1.0E-59	Ru106	2.2E-01	2.8E-02

Table A-3. (continued).

Constituent <sup>a</sup>	Maximum Leachate Concentration (pCi/L) <sup>b</sup>	Average Leachate Concentration (pCi/L) <sup>b</sup>	Constituent <sup>a</sup>	Maximum Leachate Concentration (pCi/L) <sup>b</sup>	Average Leachate Concentration (pCi/L) <sup>b</sup>
Pm148m	3.4E-57	2.1E-58	Sb124	4.1E-39	2.6E-40
Po210	6.8E-06	5.0E-07	Sb125	1.9E+02	5.1E+01
Po211	4.6E-09	2.9E-10	Sb126	4.1E-01	2.6E-02
Po212	2.2E-03	1.4E-04	Sb126m	2.9E+00	1.8E-01
Po213	2.9E-07	1.8E-08	Sc46	9.2E-20	6.0E-21
Po214	3.7E-05	2.3E-06	Se79	4.1E+01	4.1E+01
Po215	1.2E-04	7.6E-06	Sm146	1.8E-09	1.8E-09
Sm147	1.7E-05	1.7E-05	Th231	1.6E+00	1.0E-01
Sm148	4.2E-12	4.2E-12	Th232	1.6E+00	1.6E+00
Sm149	2.1E-11	2.1E-11	Th234	1.7E-02	1.1E-03
Sm151	1.4E+03	1.3E+03	Tl207	1.8E-04	1.1E-05
Sn117m	0.0E+00	0.0E+00	Tl208	2.0E-03	1.2E-04
Sn119m	1.1E-06	1.2E-07	Tl209	1.1E-08	6.6E-10
Sn121m	2.1E-01	1.9E-01	Tm170	2.7E-25	1.9E-26
Sn123	6.5E-16	4.7E-17	Tm171	6.6E-12	1.4E-12
Sn125	0.0E+00	0.0E+00	U230	0.0E+00	0.0E+00
Sn126	1.1E+00	1.1E+00	U232	8.8E-02	8.2E-02
Sr89	5.0E-42	3.1E-43	U233	4.2E-03	4.2E-03
Sr90	1.9E+06	1.6E+06	U234	9.9E+02	9.9E+02
Tb160	1.3E-33	8.5E-35	U235	1.8E+01	1.8E+01
Tb161	0.0E+00	0.0E+00	U236	3.3E+01	3.3E+01
Tc98	6.8E-04	6.6E-04	U237	0.0E+00	0.0E+00
Tc99	2.2E+04	2.2E+04	U238	3.2E+02	3.2E+02
Te123	3.6E-14	3.6E-14	U240	4.2E-09	2.6E-10

Table A-3. (continued).

Constituent <sup>a</sup>	Maximum Leachate Concentration (pCi/L) <sup>b</sup>	Average Leachate Concentration (pCi/L) <sup>b</sup>	Constituent <sup>a</sup>	Maximum Leachate Concentration (pCi/L) <sup>b</sup>	Average Leachate Concentration (pCi/L) <sup>b</sup>
Te123m	2.4E-22	1.7E-23	Xe127	2.6E-68	1.6E-69
Te125m	1.8E+01	1.1E+00	Xe129m	0.0E+00	0.0E+00
Te127	7.5E-19	4.7E-20	Xe131m	4.5E-108	2.8E-109
Te127m	7.6E-19	5.3E-20	Xe133	0.0E+00	0.0E+00
Te129	5.4E-70	3.4E-71	Y90	1.3E+05	8.4E+03
Te129m	8.6E-70	5.4E-71	Y91	2.4E-36	1.5E-37
Th226	2.2E-116	1.4E-117	Zn65	1.7E-07	1.6E-08
Th227	1.8E-04	1.1E-05	Zr93	1.4E+00	1.4E+00
Th228	3.3E-01	6.7E-02	Zr95	<u>4.9E-25</u>	<u>3.1E-26</u>
Th229	5.1E-07	5.1E-07		2.3E+07	1.4E+07
Th230	1.7E+00	1.7E+00			

a. Constituents based on the design Inventory (2001 EDF-264)

b. Peak and average concentrations during the 15 year active life of the landfill assuming the entire mass is placed in the landfill (EDF-ER-274)

c. Constituents Kr-81 and Kr-85 are gaseous elements, so are not part of the leachate.

Table A-4. Radionuclide design absorption rate.

Constituent <sup>a</sup>	Landfill Design Absorption Rate Rads/Hour <sup>b</sup>	Evaporation Pond Design Absorption Rate Rads/Hour <sup>b</sup>	Constituent <sup>a</sup>	Landfill Design Absorption Rate Rads/Hour <sup>b</sup>	Evaporation Pond Design Absorption Rate Rads/Hour <sup>b</sup>
Ac225	3.95E-14	3.55E-13	Cm250	1.07E-32	9.61E-32
Ac227	2.15E-13	1.94E-12	Co57	3.13E-09	2.82E-08
Ac228	2.73E-17	2.46E-16	Co58	3.40E-22	3.06E-21
Ag106	1.53E-15	1.38E-14	Co60	2.98E-03	2.68E-02
Ag108	8.63E-07	7.77E-06	Cr51	1.65E-61	1.48E-60
Ag108m	0.00E+0	0.00E+0	Cs132	0.00E+0	0.00E+0
Ag109m	2.83E-19	2.54E-18	Cs134	2.29E-06	2.06E-05
Ag110	4.15E-17	3.73E-16	Cs135	2.40E-10	2.16E-09
Ag110m	1.03E-14	9.26E-14	Cs136	0.00E+0	0.00E+0
Ag111	0.00E+0	0.00E+0	Cs137	4.96E-04	4.47E-03
Am241	2.31E-05	2.08E-04	Er169	0.00E+0	0.00E+0
Am242	1.52E-12	1.37E-11	Eu150	8.84E-16	7.96E-15
Am242m	5.19E-13	4.67E-12	Eu152	2.16E-04	1.94E-03
Am243	3.13E-10	2.81E-09	Eu154	2.19E-04	1.97E-03
Am245	0.00E+0	0.00E+0	Eu155	3.78E-06	3.40E-05
Am246	3.07E-32	2.76E-31	Eu156	0.00E+0	0.00E+0
At217	3.59E-10	3.23E-09	Fe-59	1.59E-41	1.43E-40
Ba136m	0.00E+0	0.00E+0	Fr221	3.90E-14	3.51E-13
Ba137m	1.82E-02	1.64E-01	Fr223	1.46E-14	1.31E-13
Ba140	0.00E+0	0.00E+0	Gd152	1.45E-20	1.30E-19
Be10	5.50E-14	4.95E-13	Gd153	7.60E-19	6.84E-18
Bi210	2.53E-13	2.27E-12	H3	2.79E-04	2.52E-03
Bi211	7.19E-11	6.47E-10	Hf181	7.62E-44	6.85E-43
Bi212	9.29E-10	8.36E-09	Ho166m	1.12E-12	1.01E-11
Bi213	0.00E+0	0.00E+0	I129	1.02E-04	9.15E-04
Bi214	7.20E-12	6.48E-11	I131	0.00E+0	0.00E+0
Bk249	1.06E-30	9.53E-30	In114	2.31E-61	2.08E-60
Bk250	1.36E-33	1.22E-32	In114m	7.21E-62	6.49E-61
C14	2.68E-11	2.41E-10	In115	1.34E-19	1.21E-18
Cd109	9.48E-19	8.54E-18	In115m	0.00E+0	0.00E+0
Cd113m	2.95E-06	2.65E-05	K40	4.62E-06	4.16E-05
Cd115m	2.62E-59	2.36E-58	Kr81	0.00E+0	0.00E+0
Ce141	5.30E-79	4.77E-78	Kr85	0.00E+0	0.00E+0

Table A-4. (continued).

Constituent <sup>a</sup>	Landfill Design Absorption Rate Rads/Hour <sup>b</sup>	Evaporation Pond Design Absorption Rate Rads/Hour <sup>b</sup>	Constituent <sup>a</sup>	Landfill Design Absorption Rate Rads/Hour <sup>b</sup>	Evaporation Pond Design Absorption Rate Rads/Hour <sup>b</sup>
Ce142	0.00E+0	0.00E+0	La138	3.74E-112	3.37E-111
Ce144	2.40E-11	2.16E-10	La140	0.00E+0	0.00E+0
Cf249	2.98E-22	2.69E-21	Mn54	1.93E-14	1.73E-13
Cf250	1.48E-22	1.33E-21	Nb92	5.70E-25	5.13E-24
Cf251	6.60E-25	5.94E-24	Nb93m	2.43E-10	2.19E-09
Cf252	2.70E-29	2.43E-28	Nb94	9.04E-12	8.13E-11
Cm241	3.30E-89	2.97E-88	Nb95	2.31E-39	2.08E-38
Cm242	4.91E-24	4.42E-23	Nb95m	2.70E-42	2.43E-41
Cm243	3.22E-13	2.90E-12	Nd144	1.54E-16	1.39E-15
Cm244	1.56E-10	1.40E-09	Nd147	0.00E+0	0.00E+0
Cm245	6.57E-15	5.92E-14	Np235	4.92E-18	4.43E-17
Cm246	1.43E-16	1.29E-15	Np236	1.75E-13	1.57E-12
Cm247	5.02E-23	4.52E-22	Np237	2.30E-05	2.07E-04
Cm248	1.35E-23	1.22E-22	Np238	1.30E-12	1.17E-11
Np239	1.02E-09	9.22E-09	Rh103m	1.26E-65	1.13E-64
Np240	3.29E-19	2.96E-18	Rh106	2.10E-08	1.89E-07
Np240m	1.78E-16	1.60E-15	Rn218	8.91E-119	8.02E-118
Pa231	4.12E-11	3.71E-10	Rn219	1.37E-07	1.24E-06
Pa233	1.93E-09	1.74E-08	Rn220	3.45E-06	3.10E-05
Pa234	7.31E-13	6.58E-12	Rn222	3.38E-08	3.04E-07
Pa234m	1.55E-10	1.39E-09	Ru103	1.20E-35	1.08E-34
Pb209	5.70E-15	5.13E-14	Ru106	5.17E-10	4.65E-09
Pb210	2.53E-14	2.27E-13	Sb124	5.54E-46	4.99E-45
Pb211	5.50E-12	4.95E-11	Sb125	5.84E-06	5.26E-05
Pb212	1.06E-10	9.51E-10	Sb126	7.48E-08	6.73E-07
Pb214	1.80E-12	1.62E-11	Sb126m	3.79E-07	3.41E-06
Pd107	2.19E-10	1.97E-09	Sc46	1.16E-26	1.04E-25
Pm146	1.23E-09	1.10E-08	Se79	1.27E-07	1.14E-06
Pm147	5.86E-06	5.28E-05	Sm146	2.67E-16	2.40E-15
Pm148	1.28E-65	1.15E-64	Sm147	2.29E-12	2.06E-11
Pm148m	4.40E-64	3.96E-63	Sm148	4.98E-19	4.48E-18
Po210	2.14E-12	1.92E-11	Sm149	0.00E+00	0.00E+00
Po211	2.02E-15	1.82E-14	Sm151	1.66E-06	1.49E-05
Po212	1.14E-09	1.03E-08	Sn117m	0.00E+0	0.00E+0

Table A-4. (continued).

Constituent <sup>a</sup>	Landfill Design Absorption Rate Rads/Hour <sup>b</sup>	Evaporation Pond Design Absorption Rate Rads/Hour <sup>b</sup>	Constituent <sup>a</sup>	Landfill Design Absorption Rate Rads/Hour <sup>b</sup>	Evaporation Pond Design Absorption Rate Rads/Hour <sup>b</sup>
Po213	1.44E-13	1.30E-12	Sn119m	5.91E-15	5.32E-14
Po214	1.71E-11	1.54E-10	Sn121m	3.74E-11	3.36E-10
Po215	5.36E-11	4.83E-10	Sn123	2.03E-23	1.83E-22
Po216	1.49E-09	1.34E-08	Sn125	0.00E+0	0.00E+0
Po218	1.34E-11	1.20E-10	Sn126	2.42E-08	2.18E-07
Pr143	0.00E+0	0.00E+0	Sr89	1.72E-49	1.55E-48
Pr144	5.64E-10	5.08E-09	Sr90	6.16E-02	5.55E-01
Pr144m	7.44E-14	6.70E-13	Tb160	1.07E-40	9.59E-40
Pu236	1.36E-11	1.22E-10	Tb161	6.13E-11	5.52E-10
Pu237	3.20E-66	2.88E-65	Tc 98	1.11E-04	1.00E-03
Pu238	5.45E-04	4.91E-03	Tc99	3.67E-23	3.31E-22
Pu239	1.46E-05	1.31E-04	Te123	3.45E-30	3.10E-29
Pu240	3.29E-06	2.96E-05	Te123m	1.72E-07	1.55E-06
Pu241	1.42E-07	1.28E-06	Te125m	1.01E-26	9.13E-26
Pu242	5.03E-10	4.53E-09	Te127	4.11E-27	3.69E-26
Pu243	5.30E-23	4.77E-22	Te127m	1.94E-77	1.74E-76
Pu244	4.97E-17	4.47E-16	Te129	1.57E-77	1.42E-76
Pu246	9.07E-33	8.17E-32	Te129m	0.00E+0	0.00E+0
Ra222	4.56E-122	4.10E-121	Th226	8.21E-123	7.39E-122
Ra223	7.11E-11	6.40E-10	Th227	6.54E-11	5.89E-10
Ra224	1.87E-09	1.68E-08	Th228	1.06E-07	9.54E-07
Ra225	3.63E-15	3.27E-14	Th229	1.54E-13	1.39E-12
Ra226	1.35E-06	1.21E-05	Th230	4.84E-07	4.36E-06
Ra228	1.05E-18	9.43E-18	Th231	1.71E-08	1.54E-07
Rb86	0.00E+0	0.00E+0	Th232	3.72E-07	3.35E-06
Rb87	9.50E-13	8.55E-12	Th234	6.78E-11	6.10E-10
Rh102	2.71E-12	2.44E-11	Tl207	5.38E-12	4.84E-11
Tl208	4.66E-10	4.20E-09			
Tl209	2.48E-15	2.24E-14			
Tm170	5.29E-33	4.76E-32			
Tm171	1.04E-20	9.33E-20			
U230	0.00E+0	0.00E+0			
U232	2.80E-08	2.52E-07			
U233	1.21E-09	1.09E-08			

Table A-4. (continued).

Constituent <sup>a</sup>	Landfill Design Absorption Rate Rads/Hour <sup>b</sup>	Evaporation Pond Design Absorption Rate Rads/Hour <sup>b</sup>	Constituent <sup>a</sup>	Landfill Design Absorption Rate Rads/Hour <sup>b</sup>	Evaporation Pond Design Absorption Rate Rads/Hour <sup>b</sup>
U234	2.83E-04	2.54E-03			
U235	4.95E-06	4.46E-05			
U236	8.94E-06	8.05E-05			
U237	0.00E+0	0.00E+0			
U238	8.06E-05	7.25E-04			
U240	3.99E-17	3.59E-16			
Xe127	4.85E-76	4.36E-75			
Xe129m	0.00E+0	0.00E+0			
Xe131m	4.33E-116	3.90E-115			
Xe133	0.00E+0	0.00E+0			
Y90	7.76E-03	6.99E-02			
Y91	8.79E-44	7.91E-43			
Zn65	5.88E-15	5.29E-14			
Zr93	1.66E-09	1.49E-08			
Zr95	2.47E-32	2.22E-31			
Total Design Absorption Rate	9.30E-02 rads/hr	8.37E-01 rads/hr			
Total Design Absorption	1.22E+04 rads	1.10E+05 rads			

a. Constituents based on the design Inventory (EDF-ER-264)

b. Based on average concentrations during the 15 year active life of the landfill assuming the entire mass is placed in the landfill (EDF-ER-274)

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### **Appendix B**

### **Geomembrane Dose Calculations**

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## Appendix B-1

### Geomembrane Dose in the Landfill

#### MONTGOMERY WATSON HARZA

Description: Radiation dosage to ICDF liner resulting from leachate exposure

Project #: 2470178

Prepared by: J. Thompson

Date: 10/6/01

Checked by: B. Adams/J. Pellicer

Date: 12/7/01

**VARIABLES**

Liner Thickness =	60 mils
Liner density =	0.94 g/cm <sup>3</sup>
Depth of leachate =	4 cm

#### CONVERSIONS

pCi/Ci =	1.00E+12
cm <sup>3</sup> /l =	1000
cm/mil =	2.54E-03
(dis/s)/Ci =	3.70E+10
sec/hr =	3600
g/kg =	1.00E+03
eV/Mev =	1.00E+06
J/eV =	1.60E-19
rad =	0.01 J/kg
rad/Gy =	100

Hand Calculation for Calculating Dose for Ac225							
1.14e-7pCi	x	liter	x	Ci	x	4cm <sup>3</sup>	= 4.56e-22 Ci
liter		1000cm <sup>3</sup>		1e12pCi			
4.56e-22 Ci	x	3.7e10 dis	x	3600 sec	x	5.832 MeV	= 0.3542 eV
		Ci sec		hour		dis	MeV
Liner Mass:	60 mil	x	in	2.54 cm	x	0.94 g	= 1.432e-4 kg
		1000 mil		in		cm <sup>3</sup>	kg
0.3542 eV	x	1.6e-19 J	x	1	x	rad kg	= 3.95e-14 rad
hour		eV				0.01 J	hr

Constituent	ICDF Average Activity Concentration (pCi/L)	ICDF Average Activity Concentration (Ci/cm <sup>3</sup> )	Disintegration Energy from Alpha Radiation (MeV/dis) <sup>a</sup>	Disintegration Energy from Beta Radiation (MeV/dis) <sup>a</sup>	Disintegration Energy from Gamma Radiation (MeV/dis) <sup>a</sup>	Disintegration Energy from Electron Radiation (MeV/dis) <sup>a</sup>	Total Disintegration Energy (MeV/dis) <sup>b</sup>	ICDF Liner Radiation Dose (Rads/hr)
Ac225	1.14E-07	1.14E-22	5.794750712		0.015675725	0.021753375	5.832179811	3.95E-14
Ac227	4.54E-05	4.54E-20	0.067076762	0.009519	0.000269356	0.002766609	0.079631727	2.15E-13
Ac228	3.38E-10	3.38E-25		0.365039719	0.926920369	0.064207018	1.356167107	2.73E-17
Ag108	4.10E-08	4.10E-23		0.609441	0.017742571	0.000104798	0.627288369	1.53E-15
Ag108m	8.88E+00	8.88E-15			1.619571716	0.014175304	1.63374702	8.63E-07
Ag109m	5.46E-11	5.46E-26			0.011251468	0.075708836	0.086960304	2.83E-19
Ag110	5.75E-10	5.74855E-25		1.181485222	0.030569692	1.49286E-05	1.212069842	4.15E-17
Ag110m	6.16E-08	6.15802E-23		0.065497652	2.740392268	0.002891351	2.808781272	1.03E-14
Am241	7.01E+01	7.00857E-14	5.4776265		0.028100691	0.029402026	5.535129217	2.31E-05
Am242	1.33E-04	1.33277E-19		0.159206	0.01777726	0.014518168	0.191501428	1.52E-12
Am242m	1.33E-04	1.32877E-19	0.02491305		0.004697851	0.036045937	0.065656838	5.19E-13
Am243	9.82E-04	9.8225E-19	5.26454376		0.058325807	0.025255628	5.348125195	3.13E-10
Am246	4.06E-25	4.06494E-40		0.2600814	0.979943558	0.029091734	1.269116692	3.07E-32
At217	8.54E-04	8.53567E-19	7.065707158				7.065707158	3.59E-10
Ba137m	4.62E+05	4.61732E-10			0.597793455	0.063669106	0.661462561	1.82E-02
Be 10	4.57E-06	4.56737E-21		0.2025			0.2025	5.50E-14
Bi210	1.09E-05	1.09161E-20		0.389			0.389	2.53E-13
Bi211	1.83E-04	1.82992E-19	6.549152819	0.000476658	0.047468126	0.009283362	6.606380966	7.19E-11
Bi212	5.53E-03	5.52598E-18	2.173446631	0.459769426	0.184126961	0.008766847	2.826109865	9.29E-10
Bi214	5.62E-05	5.61657E-20		0.631854371	1.509899923	0.011891859	2.153646154	7.20E-12
Bk249	5.39E-22	5.39325E-37		0.03299967			0.03299967	1.06E-30
Bk250	1.94E-26	1.93749E-41		0.26636366	0.886746664	0.02698613	1.180096454	1.36E-33
C 14	9.11E-03	9.1119E-18		0.04947			0.04947	2.68E-11
Cd109	8.11E-10	8.11386E-25			0.014910997	0.004730612	0.019641609	9.48E-19
Cd113m	2.67E+02	2.67401E-13		0.185357358			0.185357358	2.95E-06
Cd115m	7.02E-52	7.01999E-67		0.606227346	0.021898515		0.62812586	2.62E-59
Ce141	3.61E-71	3.60929E-86		0.1446745	0.076850362	0.025152933	0.246677795	5.30E-79
Ce144	3.61E-03	3.61187E-18		0.0832751	0.019274755	0.009263998	0.111813852	2.40E-11
Cf249	8.09E-16	8.08594E-31	5.832326913		0.331949482	0.037464582	6.201740977	2.98E-22
Cf250	4.13E-16	4.13182E-31	6.019605686		0.001194765	0.0044555842	6.025256294	1.48E-22
Cf251	1.87E-18	1.86599E-33	5.6630136		0.121953755	0.159025305	5.94399266	6.60E-25
Cf252	4.40E-20	4.39839E-35			0.006078129	0.004222783	0.010300912	2.70E-29
Cm241	3.24E-81	3.24048E-96	0.0592	0.112			0.1712	3.30E-89
Cm242	1.35E-17	1.34831E-32	6.104058752		0.00886198	0.007548684	6.120469416	4.91E-24

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Constituent	ICDF Average Activity Concentration (pCi/L)	ICDF Average Activity Concentration (Ci/cm <sup>3</sup> )	Disintegration Energy from Alpha Radiation (MeV/dis) <sup>a</sup>	Disintegration Energy from Beta Radiation (MeV/dis) <sup>a</sup>	Disintegration Energy from Gamma Radiation (MeV/dis) <sup>a</sup>	Disintegration Energy from Electron Radiation (MeV/dis) <sup>a</sup>	Total Disintegration Energy (MeV/dis) <sup>b</sup>	ICDF Liner Radiation Dose (Rads/hr)
Cm248	4.88E-17	4.88339E-32	4.652098978		0.001053916	0.004771581	4.657924475	1.35E-23
Cm250	1.38E-25	1.3823E-40	1.2975	0.00126			1.29876	1.07E-32
Co-57	3.67E-01	3.67011E-16			0.125116492	0.018266873	0.143383365	3.13E-09
Co-58	5.84E-15	5.84275E-30			0.97577339	0.003554852	0.979328243	3.40E-22
Co-60	1.92E+04	1.92228E-11		0.09579	2.505813093		2.601603093	2.98E-03
Cr-51	7.66E-53	7.66009E-68			0.032581687	0.003609603	0.036191289	1.65E-61
Cs-134	2.24E+01	2.24236E-14		0.156843574	1.555088123	0.005168308	1.717100005	2.29E-06
Cs135	7.16E-02	7.16176E-17		0.0563			0.0563	2.40E-10
Cs137	4.89E+04	4.88614E-11		0.1707536			0.1707536	4.96E-04
Eu150	5.09E-08	5.08758E-23		0.292			0.292	8.84E-16
Eu152	2.85E+03	2.84526E-12		0.083686791	1.152309414	0.040284747	1.276280952	2.16E-04
Eu154	2.41E+03	2.41379E-12		0.225199121	1.253240971	0.04847077	1.526910861	2.19E-04
Eu155	5.19E+02	5.18807E-13		0.045440452	0.060584231	0.016346264	0.122371015	3.78E-06
Fe-59	2.05E-34	2.0497E-49		0.117452592	1.188458138		1.30591073	1.59E-41
Fr221	1.02E-07	1.02416E-22	6.35419518		0.030918345	0.009345796	6.394459322	3.90E-14
Fr223	5.65E-07	5.64646E-22		0.341682282	0.054245778	0.038798691	0.434726751	1.46E-14
Gd152	1.13E-13	1.13275E-28	2.1496				2.1496	1.45E-20
Gd153	8.38E-11	8.38004E-26			0.110492119	0.041857881	0.15235	7.60E-19
H 3	8.26E+05	8.26041E-10		0.005685			0.005685	2.79E-04
Hf-181	1.73E-36	1.73311E-51		0.118616	0.544135316	0.075669588	0.738420904	7.62E-44
Ho166m	1.08E-05	1.07982E-20		0.040363706	1.59696433	0.103964407	1.741292443	1.12E-12
I129	2.16E+04	2.16334E-11		0.0409	0.024638767	0.013400713	0.078939479	1.02E-04
In114	4.83E-54	4.83478E-69		0.771593317	0.031986443	4.73967E-05	0.803627157	2.31E-61
In114m	5.06E-54	5.06252E-69			0.097219841	0.142167093	0.239386934	7.21E-62
In115	1.48E-11	1.48146E-26		0.152			0.152	1.34E-19
K-40	1.27E+02	1.27291E-13		0.454278782	0.155895094	0.00019193	0.610365806	4.62E-06
La140	2.21E-105	2.2065E-120		0.527461627	2.316273704	0.005168104	2.848903435	3.74E-112
Mn-54	3.86E-07	3.85666E-22			0.83600515	0.003819757	0.839824907	1.93E-14
Nb92	6.34E-18	6.34129E-33			1.503376922	0.006587855	1.509964777	5.70E-25
Nb93m	1.35E-01	1.34956E-16			0.001949851	0.02830264	0.030252491	2.43E-10
Nb94	8.83E-05	8.82572E-20		0.1458	1.573752035	0.001108272	1.720660307	9.04E-12
Nb95	4.80E-32	4.79764E-47		0.04343358	0.764449657	0.000960441	0.808843679	2.31E-39
Nb95m	1.84E-34	1.83993E-49		0.024094426	0.066299718	0.156400746	0.24679489	2.70E-42
Nd144	1.36E-09	1.36144E-24	1.9				1.9	1.54E-16
Np235	8.43E-09	8.43464E-24			0.006849299	0.00295462	0.009803919	4.92E-18
Np236	8.60E-06	8.60333E-21		0.007895	0.144249657	0.188908994	0.341053651	1.75E-13
Np237	7.98E+01	7.97825E-14	4.759362826		0.032973835	0.062385374	4.854722034	2.30E-05
Np238	2.70E-05	2.70471E-20		0.224714208	0.554083268	0.029658953	0.808456429	1.30E-12
Np239	4.14E-02	4.14422E-17		0.115125998	0.172110902	0.128163122	0.415400022	1.02E-09
Np240	3.46E-12	3.46382E-27		0.241	1.16312137	0.190279619	1.594400989	3.29E-19
Np240m	3.15E-09	3.14893E-24		0.590015065	0.333687187	0.025194589	0.948896841	1.78E-16
Pa231	1.27E-04	1.26888E-19	5.380806428		0.037179164	0.035516603	5.453502195	4.12E-11
Pa233	7.92E-02	7.91815E-17		0.0585556	0.217583236	0.133362528	0.409501364	1.93E-09
Pa234	4.98E-06	4.98489E-21		0.22297083	1.966021292	0.2744944	2.463486522	7.31E-13
Pa234m	3.11E-03	3.11453E-18		0.820374363	0.011413333	0.003045741	0.834833438	1.55E-10
Pb209	4.85E-07	4.84656E-22		0.1976			0.1976	5.70E-15
Pb210	1.09E-05	1.09161E-20		0.00651402	0.004510364	0.027874272	0.038898656	2.53E-14
Pb211	1.83E-04	1.82992E-19		0.4522909635	0.050904428	0.001625278	0.505439341	5.50E-12
Pb212	5.53E-03	5.52598E-18		0.09961888	0.14811816	0.073508769	0.321245808	1.06E-10
Pb214	5.62E-05	5.61657E-20		0.2195445	0.249218235	0.069709256	0.538471991	1.80E-12
Pd107	1.11E-01	1.11124E-16		0.033101			0.033101	2.19E-10
Pm146	2.42E-02	2.42035E-17		0.0895829	0.753108251	0.008140193	0.850831344	1.23E-09
Pm147	1.59E+03	1.58971E-12		0.061957827	3.51654E-06		0.061961344	5.86E-06
Pm148	1.66E-58	1.65511E-73		0.72568641	0.574309603	0.000924896	1.30092091	1.28E-65
Pm148m	3.43E-57	3.42833E-72		0.1454396	1.991307208	0.01855489	2.155301698	4.40E-64
Po210	6.77E-06	6.7654E-21	5.304496719		8.8341E-06		5.304505553	2.14E-12
Po211	4.56E-09	4.5606E-24	7.442553252		0.007761102		7.450314354	2.02E-15
Po212	2.19E-03	2.18667E-18	8.7849				8.7849	1.14E-09
Po213	2.89E-07	2.89342E-22	8.3769694		0.000030381		8.376999781	1.44E-13
Po214	3.75E-05	3.74513E-20	7.686985013		8.29192E-05		7.687067933	1.71E-11
Po215	1.22E-04	1.22019E-19	7.386157912		0.000149158		7.38630707	5.36E-11
Po216	3.68E-03	3.68473E-18	6.77847216		1.44882E-05		6.778486648	1.49E-09
Po218	3.75E-05	3.74513E-20	6.001296466				6.001296466	1.34E-11
Pr144	7.38E-03	7.38075E-18		1.207181838	0.031914881	0.044921056	1.284017776	5.64E-10
Pr144m	1.06E-04	1.05542E-19			0.01184728		0.01184728	7.44E-14
Pu236	3.95E-05	3.94781E-20	5.759246369		0.001823624	0.010642416	5.771712409	1.36E-11
Pu237	8.64E-58	8.63987E-73			0.053631643	0.00860943	0.062241073	3.20E-66

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Pu238	1.67E+03	1.66644E-12	5.487135213		0.001600358	0.008259555	5.496995126	5.45E-04
Pu239	4.76E+01	4.75673E-14	5.147993305		0.000654063	0.004879569	5.153526936	1.46E-05
Pu240	1.07E+01	1.07109E-14	5.15442817		0.001526154	0.008332035	5.164286359	3.29E-06
Pu241	4.56E+02	4.56263E-13		0.005229895			0.005229895	1.42E-07
Pu242	1.72E-03	1.71827E-18	4.914950908		0.001267029	0.006838836	4.923056772	5.03E-10
Pu243	4.56E-15	4.56263E-30		0.160416257	0.024856596	0.009931485	0.195204338	5.30E-23
Pu244	1.82E-10	1.81534E-25	4.59129767		0.001091163	0.00576354	4.598152374	4.97E-17
Pu246	9.87E-25	9.86952E-40		0.054192	0.100325541		0.154517541	9.07E-33
Ra222	1.17E-115	1.1686E-130	6.543645859		0.009191111	0.000710852	6.553547823	4.56E-122
Ra223	2.02E-04	2.02468E-19	5.693111445		0.135359242	0.070979646	5.899450334	7.11E-11
Ra224	5.53E-03	5.52598E-18	5.674903074		0.010016186	0.002181394	5.687100654	1.87E-09
Ra225	5.12E-07	5.11833E-22		0.09364	0.014401901	0.011183962	0.119225863	3.63E-15
Ra226	4.73E+00	4.73487E-15	4.779486739		0.006748	0.003450946	4.789685685	1.35E-06
Ra228	1.52E-09	1.52191E-24		0.0099	6.67E-09	0.001668	0.011568007	1.05E-18
Rb87	2.02E-04	2.02493E-19		0.0788			0.0788	9.50E-13
Rh102	5.71E-04	5.71027E-19		0.0798			0.0798	2.71E-12
Rh103m	5.43E-57	5.42777E-72			0.001719179	0.03714169	0.038860869	1.26E-65
Rh106	2.18E-01	2.18418E-16		1.412048767	0.207318974		1.61936774	2.10E-08
Rn218	2.10E-112	2.0999E-127	7.13224054		0.000755544		7.132996084	8.91E-119
Rn219	3.38E-01	3.3765E-16	6.768687931		0.057349406	0.006215139	6.832252476	1.37E-07
Rn220	9.22E+00	9.2155E-15	6.287774939		0.000522244		6.288297183	3.45E-06
Rn222	1.03E-01	1.03486E-16	5.48922225		0.00038912		5.48961137	3.38E-08
Ru103	3.65E-28	3.64513E-43		0.06754106	0.483836014	0.00219364	0.553570714	1.20E-35
Ru106	2.21E-01	2.20509E-16		0.039401			0.039401	5.17E-10
Sb124	4.14E-39	4.14237E-54		0.377755372	1.868890831	0.002369455	2.249015659	5.54E-46
Sb125	1.85E+02	1.85236E-13		0.08644006	0.432562126	0.011201711	0.530203897	5.84E-06
Sb126	4.12E-01	4.11874E-16		0.2904498	2.753144672	0.008852224	3.052446696	7.48E-08
Sb126m	2.94E+00	2.94195E-15		0.5821	1.572598561	0.010281928	2.164980488	3.79E-07
Sc-46	9.18E-20	9.1778E-35		0.112016432	2.009462055		2.121478487	1.16E-26
Se 79	4.08E+01	4.08468E-14		0.0522			0.0522	1.27E-07
Sm146	1.77E-09	1.77335E-24	2.53				2.53	2.67E-16
Sm147	1.71E-05	1.7098E-20	2.2476				2.2476	2.29E-12
Sm148	4.20E-12	4.20258E-27	1.99				1.99	4.98E-19
Sm149	2.13E-11	2.13338E-26	0	0			0	0.00E+00
Sm151	1.41E+03	1.40601E-12		0.019629664	1.26002E-05	0.000142779	0.019785044	1.66E-06
Sn119m	1.14E-06	1.14041E-21			0.011398832	0.075702053	0.087100885	5.91E-15
Sn121m	2.07E-01	2.06532E-16		0.00304			0.00304	3.74E-11
Sn123	6.47E-16	6.4725E-31		0.520527904	0.006892023		0.527419926	2.03E-23
Sn126	1.13E+00	1.1334E-15		0.2501	0.056584693	0.051902929	0.358587622	2.42E-08
Sr89	4.96E-42	4.96364E-57		0.58294069	0.000136365		0.583077055	1.72E-49
Sr90	1.90E+06	1.8965E-09		0.546			0.546	6.16E-02
Tb160	1.32E-33	1.32325E-48		0.2225914897	1.081655763	0.045293923	1.352864583	1.07E-40
Tc 98	6.80E-04	6.79832E-19		0.118	1.394806477	0.002533816	1.515340293	6.13E-11
Tc 99	2.21E+04	2.21364E-11		0.084600002	5.3616E-07		0.084600538	1.11E-04
Te123	3.62E-14	3.61635E-29			0.013085863	0.003979538	0.017065401	3.67E-23
Te123m	2.36E-22	2.35653E-37			0.147968536	0.097813431	0.245781966	3.45E-30
Te125m	1.81E+01	1.81252E-14			0.035029212	0.1243697	0.159398912	1.72E-07
Te127	7.48E-19	7.48362E-34		0.2222944359	0.004837938		0.227782297	1.01E-26
Te127m	7.60E-19	7.59597E-34		0.004605048	0.01122391	0.074989512	0.090818471	4.11E-27
Te129	5.40E-70	5.39691E-85		0.524547312	0.057653871	0.021254015	0.603455198	1.94E-77
Te129m	8.57E-70	8.56757E-85		0.211896011	0.039439344	0.057284	0.308619356	1.57E-77
Th226	2.18E-116	2.1787E-131	6.30769684		0.008516701	0.019601821	6.335815362	8.21E-123
Th227	1.82E-04	1.81633E-19	5.90223546		0.109621209	0.038621827	6.050478496	6.54E-11
Th228	3.29E-01	3.2872E-16	5.39930015		0.003074111	0.019010262	5.421384523	1.06E-07
Th229	5.12E-07	5.11833E-22	4.862233245		0.094769364	0.099685142	5.056687752	1.54E-13
Th230	1.73E+00	1.73379E-15	4.67678788		0.001405096	0.012883269	4.691076245	4.84E-07
Th231	1.61E+00	1.60797E-15		0.080038999	0.023548831	0.074878474	0.178466304	1.71E-08
Th232	1.56E+00	1.55721E-15	4.00455		0.001196619	0.010883174	4.016629793	3.72E-07
Th234	1.71E-02	1.71215E-17		0.0433679	0.009067919	0.014136614	0.066572433	6.78E-11
Tl207	1.83E-04	1.82539E-19		0.4932555	0.002169023		0.495424523	5.38E-12
Tl208	1.98E-03	1.97939E-18		0.554863585	3.369590402	0.034133866	3.958587853	4.66E-10
Tl209	1.05E-08	1.05084E-23		1.8248	2.117940734	0.028724369	3.971465102	2.48E-15
Tm170	2.66E-25	2.65672E-40		0.315252	0.005426825	0.014066319	0.334745144	5.29E-33
Tm171	6.64E-12	6.64218E-27		0.0248128	0.000683304	0.000721114	0.026217219	1.04E-20
U232	8.83E-02	8.8251E-17	5.306496425		0.001781837	0.014381205	5.322659468	2.80E-08
U233	4.23E-03	4.22558E-18	4.813433579		0.000718117	0.003004358	4.817156054	1.21E-09
U234	9.95E+02	9.94693E-13	4.763028496		0.001476859	0.011293806	4.775799161	2.83E-04

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<b>Constituent</b>	<b>ICDF Average Activity Concentration (pCi/L)</b>	<b>ICDF Average Activity Concentration (Ci/cm<sup>3</sup>)</b>	<b>Disintegration Energy from Alpha Radiation (MeV/dis)<sup>a</sup></b>	<b>Disintegration Energy from Beta Radiation (MeV/dis)<sup>a</sup></b>	<b>Disintegration Energy from Gamma Radiation (MeV/dis)<sup>a</sup></b>	<b>Disintegration Energy from Electron Radiation (MeV/dis)<sup>a</sup></b>	<b>Total Disintegration Energy (MeV/dis)<sup>b</sup></b>	<b>ICDF Liner Radiation Dose (Rads/hr)</b>
U235	1.82E+01	1.81903E-14	4.378449		0.153592927	0.041995511	4.574037438	4.95E-06
U236	3.34E+01	3.33559E-14	4.4925232		0.001373011	0.009564051	4.503460262	8.94E-06
U238	3.22E+02	3.22148E-13	4.1940197		0.001212454	0.008504387	4.203736541	8.06E-05
U240	4.19E-09	4.18818E-24		0.125	0.006717716	0.028465325	0.160183041	3.99E-17
Xe127	2.63E-68	2.63427E-83			0.278982226	0.030144757	0.309126983	4.85E-76
Xe131m	4.49E-108	4.48535E-123			0.02009925	0.142249615	0.162348865	4.33E-116
Y90	1.35E+05	1.34525E-10		0.93471862		0.035127416	0.969846036	7.76E-03
Y91	2.44E-36	2.43696E-51		0.6022883	0.0036147		0.605903	8.79E-44
Zn65	1.68E-07	1.67979E-22			0.583769699	0.004560562	0.588330261	5.88E-15
Zr93	1.43E+00	1.4275E-15		0.0195			0.0195	1.66E-09
Zr95	4.87E-25	4.87454E-40		0.116123	0.73494917		0.85107217	2.47E-32
<b>Total Absorbed Dose Rate in Rads/Hour</b>							<b>9.30E-02</b>	
<b>Total Absorbed Dose For 15 year Operational Life in Rads</b>								<b>1.22E+04</b>

References:

- a. Disintigration energy based on the total energy reported in the following sources:  
 Computer software: Radiation Decay Version 3.5 developed by Professor Charles Hacker, Griffith University, Gold Coast, Australia  
 Handbook of Health Physics and Radiological Health, 3rd Edition, edited by Bernard Shleien, Lester A. Slaback Jr., and Brian Kent Birkby, Baltimore, Maryland, 1998  
 National Nuclear Data Center web site, Decay in the MIRD format, [www.nndc.bnl.gov/nndc/formmird.html](http://www.nndc.bnl.gov/nndc/formmird.html)
- b. Total disintigration energy is the sum of alpha, beta, gamma, and electron energies.

## Appendix B-2

### Geomembrane Dose in the Evaporation Pond

#### MONTGOMERY WATSON HARZA

Description: Radiation dosage to ICDF evaporation ponds liner resulting from leachate exposure

Project #: 2470178

Prepared by: J. Thompson

Date: 10/6/01

Checked by: B. Adams/J. Pellicer

Date: 12-7-01

#### VARIABLES

Liner Thickness =	60 mils
Liner density =	0.94 g/cm <sup>3</sup>
Depth of leachate =	36 cm

#### CONVERSIONS

pCi/Ci =	1.00E+12
cm <sup>3</sup> /l =	1000
cm/mil =	2.54E-03
(dis/s)/Ci =	3.70E+10
sec/hr =	3600
g/kg =	1.00E+03
eV/Mev =	1.00E+06
J/eV =	1.60E-19
rad/Gy =	100

Constituent	ICDF Average Activity Concentration (pCi/L)	ICDF Average Activity Concentration (Ci/cm <sup>3</sup> )	Disintegration Energy from Alpha Radiation (MeV/dis) <sup>a</sup>	Disintegration Energy from Beta Radiation (MeV/dis) <sup>a</sup>	Disintegration Energy from Gamma Radiation (MeV/dis) <sup>a</sup>	Disintegration Energy from Electron Radiation (MeV/dis) <sup>a</sup>	Total Disintegration Energy (MeV/dis) <sup>b</sup>	ICDF Liner Radiation Dose (Rads/hr)
Ac225	1.1E-07	1.14E-22	5.794750712		0.015675725	0.021753375	5.832179811	3.55E-13
Ac227	4.5E-05	4.54E-20	0.067076762	0.009519	0.000269356	0.002766609	0.079631727	1.94E-12
Ac228	3.4E-10	3.38E-25		0.365039719	0.926920369	0.064207018	1.356167107	2.46E-16
Ag108	4.1E-08	4.10E-23		0.609441	0.017742571	0.000104798	0.627288369	1.38E-14
Ag108m	8.9E+00	8.88E-15			1.619571716	0.014175304	1.63374702	7.77E-06
Ag109m	5.5E-11	5.46E-26			0.011251468	0.075708836	0.086960304	2.54E-18
Ag110	5.7E-10	5.74855E-25			1.181485222	0.030569692	1.49286E-05	1.212069842
Ag110m	6.2E-08	6.15802E-23			0.065497652	2.740392268	0.002891351	2.808781272
Am241	7.0E+01	7.00857E-14	5.4776265		0.028100691	0.029402026	5.535129217	2.08E-04
Am242	1.3E-04	1.33277E-19		0.159206	0.01777726	0.014518168	0.191501428	1.37E-11
Am242rm	1.3E-04	1.32877E-19	0.02491305		0.004697851	0.036045937	0.065656838	4.67E-12
Am243	9.8E-04	9.8225E-19	5.26454376		0.058325807	0.025255628	5.348125195	2.81E-09
Am246	4.1E-25	4.06494E-40		0.2600814	0.979943558	0.029091734	1.269116692	2.76E-31
At217	8.5E-04	8.53567E-19	7.065707158				7.065707158	3.23E-09
Ba137m	4.6E+05	4.61732E-10			0.597793455	0.063669106	0.661462561	1.64E-01
Be 10	4.6E-06	4.56737E-21		0.2025			0.2025	4.95E-13
Bi210	1.1E-05	1.09161E-20		0.389			0.389	2.27E-12
Bi211	1.8E-04	1.82992E-19	6.549152819	0.000476658	0.047468126	0.009283362	6.606380966	6.47E-10
Bi214	5.6E-05	5.61657E-20		0.631854371	1.509899923	0.011891859	2.153646154	6.48E-11
Bk249	5.4E-22	5.39325E-37		0.03299967			0.03299967	9.53E-30
Bk250	1.9E-26	1.93749E-41		0.26636366	0.886746664	0.02698613	1.180096454	1.22E-32
Cd109	8.1E-10	8.11386E-25			0.014910997	0.004730612	0.019641609	8.54E-18
Cd113m	2.7E+02	2.67401E-13		0.185357358			0.185357358	2.65E-05
Ce141	3.6E-71	3.60929E-86		0.1446745	0.076850362	0.025152933	0.246677795	4.77E-78
Ce144	3.6E-03	3.61187E-18		0.0832751	0.019274755	0.009263998	0.111813852	2.16E-10
Cf249	8.1E-16	8.08594E-31	5.832326913		0.331949482	0.037464582	6.201740977	2.69E-21
Cf250	4.1E-16	4.13182E-31	6.019605686		0.001194765	0.004455842	6.025256294	1.33E-21
Cf251	1.9E-18	1.86599E-33	5.6630136		0.121953755	0.159025305	5.94399266	5.94E-24
Cm241	3.2E-81	3.24048E-96	0.0592	0.112			0.1712	2.97E-88
Cm242	1.3E-17	1.34831E-32	6.104058752		0.00886198	0.007548684	6.120469416	4.42E-23
Cm243	8.9E-07	8.883E-22	5.834234959		0.132613797	0.122747969	6.089596726	2.90E-12
Cm244	4.5E-04	4.50948E-19	5.796499747		0.001490051	0.006438553	5.804428351	1.40E-09
Cm245	2.0E-08	2.00547E-23	5.360616241		0.076920127	0.069851389	5.507387757	5.92E-14
Cm246	4.5E-10	4.47549E-25	5.37557179		0.001325463	0.006093795	5.382991049	1.29E-15
Cm247	1.6E-16	1.59758E-31	4.946722		0.317367237	0.014739412	5.278828648	4.52E-22
Cm248	4.9E-17	4.88339E-32	4.652098978		0.001053916	0.004771581	4.657924475	1.22E-22
Co-57	3.7E-01	3.67011E-16			0.125116492	0.018266873	0.143383365	2.82E-08
Co-58	5.8E-15	5.84275E-30			0.97577339	0.003554852	0.979328243	3.06E-21
Co-60	1.9E+04	1.92228E-11		0.09579	2.505813093		2.601603093	2.68E-02
Cr-51	7.7E-53	7.66009E-68			0.032581687	0.003609603	0.036191289	1.48E-60
Cs-134	2.2E+01	2.24236E-14		0.156843574	1.555088123	0.005168308	1.71710005	2.06E-05
Cs135	7.2E-02	7.16176E-17		0.0563			0.0563	2.16E-09
Cs137	4.9E+04	4.88614E-11		0.1707536			0.1707536	4.47E-03
Eu150	5.1E-08	5.08758E-23		0.292			0.292	7.96E-15
Eu152	2.8E+03	2.84526E-12		0.083686791	1.152309414	0.040284747	1.276280952	1.94E-03
Eu154	2.4E+03	2.41379E-12		0.225199121	1.253240971	0.04847077	1.526910861	1.97E-03
Eu155	5.2E+02	5.18807E-13		0.04544052	0.060584231	0.016346264	0.122371015	3.40E-05
Fe-59	2.0E-34	2.0497E-49		0.117452592	1.188458138		1.30591073	1.43E-40
Fr221	1.0E-07	1.02416E-22	6.35419518		0.030918345	0.009345796	6.394459322	3.51E-13

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Constituent	ICDF Average Activity Concentration (pCi/L)	ICDF Average Activity Concentration (Ci/cm <sup>3</sup> )	Disintegration Energy from Alpha Radiation (MeV/dis) <sup>a</sup>	Disintegration Energy from Beta Radiation (MeV/dis) <sup>a</sup>	Disintegration Energy from Gamma Radiation (MeV/dis) <sup>a</sup>	Disintegration Energy from Electron Radiation (MeV/dis) <sup>a</sup>	Total Disintegration Energy (MeV/dis) <sup>b</sup>	ICDF Liner Radiation Dose (Rads/hr)
In114m	5.1E-54	5.06252E-69			0.097219841	0.142167093	0.239386934	6.49E-61
In115	1.5E-11	1.48146E-26		0.152			0.152	1.21E-18
K-40	1.3E+02	1.27291E-13		0.454278782	0.155895094	0.00019193	0.610365806	4.16E-05
La140	2.2E-105	2.2065E-120		0.527461627	2.316273704	0.005168104	2.848903435	3.37E-111
Mn-54	3.9E-07	3.85666E-22			0.83600153	0.003819757	0.839824907	1.73E-13
Nb92	6.3E-18	6.34129E-33			1.503376922	0.006587855	1.509964777	5.13E-24
Nb93m	1.3E-01	1.34956E-16			0.001949851	0.02830264	0.030252491	2.19E-09
Nb94	8.8E-05	8.82572E-20		0.1458	1.573752035	0.001108272	1.720660307	8.13E-11
Nb95m	1.8E-34	1.83993E-49		0.024094426	0.066299718	0.156400746	0.24679489	2.43E-41
Nd144	1.4E-09	1.3614E-24	1.9				1.9	1.39E-15
Np236	8.6E-06	8.60333E-21		0.007895	0.144249657	0.188908994	0.341053651	1.57E-12
Np239	4.1E-02	4.14422E-17		0.115125998	0.172110902	0.128163122	0.415400022	9.22E-09
Np240m	3.1E-09	3.14893E-24		0.590015065	0.333687187	0.025194589	0.948896841	1.60E-15
Pa231	1.3E-04	1.26888E-19	5.380806428		0.037179164	0.035516603	5.453502195	3.71E-10
Pa233	7.9E-02	7.91815E-17		0.0585556	0.217583236	0.133362528	0.409501364	1.74E-08
Pa234	5.0E-06	4.98489E-21		0.22297083	1.966021292	0.2744944	2.463486522	6.58E-12
Pa234m	3.1E-03	3.11453E-18		0.820374363	0.011413333	0.003045741	0.834833438	1.39E-09
Pb209	4.8E-07	4.84656E-22		0.1976			0.1976	5.13E-14
Pb210	1.1E-05	1.09161E-20		0.00651402	0.004510364	0.027874272	0.038898656	2.27E-13
Pb212	5.5E-03	5.52598E-18		0.09961888	0.14811816	0.073508769	0.321245808	9.51E-10
Pb214	5.6E-05	5.61657E-20		0.2195445	0.249218235	0.069709256	0.538471991	1.62E-11
Pd107	1.1E-01	1.11124E-16		0.033101			0.033101	1.97E-09
Pm146	2.4E-02	2.42035E-17		0.0895829	0.753108251	0.008140193	0.850831344	1.10E-08
Pm147	1.6E+03	1.58971E-12		0.061957827	3.51654E-06		0.061961344	5.28E-05
Pm148	1.7E-58	1.65511E-73		0.72568641	0.574309603	0.000924896	1.30092091	1.15E-64
Pm148m	3.4E-57	3.42833E-72		0.1454396	1.991307208	0.01855489	2.155301698	3.96E-63
Po210	6.8E-06	6.7654E-21	5.304496719		8.8341E-06		5.304505553	1.92E-11
Po211	4.6E-09	4.5606E-24	7.442553252		0.007761102		7.450314354	1.82E-14
Po212	2.2E-03	2.18667E-18	8.7849				8.7849	1.03E-08
Po213	2.9E-07	2.89342E-22	8.3769694		0.000030381		8.376999781	1.30E-12
Po214	3.7E-05	3.74513E-20	7.686985013		8.29192E-05		7.687067933	1.54E-10
Po215	1.2E-04	1.22019E-19	7.386157912		0.000149158		7.38630707	4.83E-10
Po216	3.7E-03	3.68473E-18	6.77847216		1.44882E-05		6.778486648	1.34E-08
Po218	3.7E-05	3.74513E-20	6.001296466				6.001296466	1.20E-10
Pr144	7.4E-03	7.38075E-18		1.207181838	0.031914881	0.044921056	1.284017776	5.08E-09
Pr144m	1.1E-04	1.05542E-19			0.011847228		0.011847228	6.70E-13
Pu236	3.9E-05	3.94781E-20	5.759246369		0.001823624	0.010642416	5.771712409	1.22E-10
Pu237	8.6E-58	8.63987E-73			0.053631643	0.00860943	0.062241073	2.88E-65
Pu238	1.7E+03	1.66644E-12	5.487135213		0.001600358	0.008259555	5.496995126	4.91E-03
Pu239	4.8E+01	4.75673E-14	5.147993305		0.000654063	0.004879569	5.153526936	1.31E-04
Pu240	1.1E+01	1.07109E-14	5.15442817		0.001526154	0.008332035	5.164286359	2.96E-05
Pu241	4.6E+02	4.56263E-13		0.005229895			0.005229895	1.28E-06
Pu242	1.7E-03	1.71827E-18	4.914950908		0.001267029	0.006838836	4.923056772	4.53E-09
Pu243	4.6E-15	4.56263E-30		0.160416257	0.024856596	0.009931485	0.195204338	4.77E-22
Pu244	1.8E-10	1.81534E-25	4.59129767		0.001091163	0.00576354	4.598152374	4.47E-16
Pu246	9.9E-25	9.86952E-40		0.054192	0.100325541		0.154517541	8.17E-32
Ra222	1.2E-115	1.1686E-130	6.543645859		0.009191111	0.000710852	6.553547823	4.10E-121
Ra224	5.5E-03	5.52598E-18	5.674903074		0.010016186	0.002181394	5.687100654	1.68E-08
Ra225	5.1E-07	5.11833E-22		0.09364	0.014401901	0.011183962	0.119225863	3.27E-14
Ra226	4.7E+00	4.73487E-15	4.779486739		0.006748	0.003450946	4.789685685	1.21E-05
Ra228	1.5E-09	1.52191E-24		0.0099	6.67E-09	0.001668	0.011568007	9.43E-18
Rb87	2.0E-04	2.02493E-19		0.0788			0.0788	8.55E-12
Rh102	5.7E-04	5.71027E-19		0.0798			0.0798	2.44E-11
Rh103m	5.4E-57	5.42777E-72			0.001719179	0.03714169	0.038860869	1.13E-64
Rh106	2.2E-01	2.18418E-16		1.412048767	0.207318974		1.61936774	1.89E-07
Rn218	2.1E-112	2.0999E-127	7.13224054		0.000755544		7.132996084	8.02E-118
Rn219	3.4E-01	3.3765E-16	6.768687931		0.057349406	0.006215139	6.832252476	1.24E-06
Rn220	9.2E+00	9.2155E-15	6.287774939		0.000522244		6.288297183	3.10E-05
Rn222	1.0E-01	1.03486E-16	5.48922225		0.00038912		5.48961137	3.04E-07
Ru103	3.6E-28	3.64513E-43		0.06754106	0.483836014	0.00219364	0.553570714	1.08E-34
Ru106	2.2E-01	2.20509E-16		0.039401			0.039401	4.65E-09
Sb124	4.1E-39	4.14237E-54		0.377755372	1.868890831	0.002369455	2.249015659	4.99E-45
Sb125	1.9E+02	1.85236E-13		0.08644006	0.432562126	0.011201711	0.530203897	5.26E-05
Sb126	4.1E-01	4.11874E-16		0.2904498	2.753144672	0.008852224	3.052446696	6.73E-07
Sc-46	9.2E-20	9.1778E-35		0.112016432	2.009462055		2.121478487	1.04E-25
Se 79	4.1E+01	4.08468E-14		0.0522			0.0522	1.14E-06
Sm146	1.8E-09	1.77335E-24	2.53				2.53	2.40E-15
Sm147	1.7E-05	1.7098E-20	2.2476				2.2476	2.06E-11
Sm148	4.2E-12	4.20258E-27	1.99				1.99	4.48E-18

# ENGINEERING DESIGN FILE

Constituent	ICDF Average Activity Concentration (pCi/L)	ICDF Average Activity Concentration (Ci/cm <sup>3</sup> )	Disintegration Energy from Alpha Radiation (MeV/dis) <sup>a</sup>	Disintegration Energy from Beta Radiation (MeV/dis) <sup>a</sup>	Disintegration Energy from Gamma Radiation (MeV/dis) <sup>a</sup>	Disintegration Energy from Electron Radiation (MeV/dis) <sup>a</sup>	Total Disintegration Energy (MeV/dis) <sup>b</sup>	ICDF Liner Radiation Dose (Rads/hr)
Sm151	1.4E+03	1.40601E-12		0.019629664	1.26002E-05	0.000142779	0.019785044	1.49E-05
Sn119m	1.1E-06	1.14041E-21			0.011398832	0.075702053	0.087100885	5.32E-14
Sn121m	2.1E-01	2.06532E-16		0.00304			0.00304	3.36E-10
Sn123	6.5E-16	6.4725E-31		0.520527904	0.006892023		0.527419926	1.83E-22
Sn126	1.1E+00	1.1334E-15		0.2501	0.056584693	0.051902929	0.358587622	2.18E-07
Sr89	5.0E-42	4.96364E-57		0.58294069	0.000136365		0.583077055	1.55E-48
Sr90	1.9E+06	1.8965E-09		0.546			0.546	5.55E-01
Tb160	1.3E-33	1.32325E-48		0.225914897	1.081655763	0.045293923	1.352864583	9.59E-40
Tc 98	6.8E-04	6.79832E-19		0.118	1.394806477	0.002533816	1.515340293	5.52E-10
Tc 99	2.2E+04	2.21364E-11		0.084600002	5.3616E-07		0.084600538	1.00E-03
Te123	3.6E-14	3.61635E-29			0.013085863	0.003979538	0.017065401	3.31E-22
Te123m	2.4E-22	2.35653E-37			0.147968536	0.097813431	0.245781966	3.10E-29
Te125m	1.8E+01	1.81252E-14			0.035029212	0.1243697	0.159398912	1.55E-06
Te127m	7.6E-19	7.59597E-34		0.004605048	0.01122391	0.074989512	0.090818471	3.69E-26
Te129	5.4E-70	5.39691E-85		0.524547312	0.057653871	0.021254015	0.603455198	1.74E-76
Te129m	8.6E-70	8.56757E-85		0.211896011	0.039439344	0.057284	0.308619356	1.42E-76
Th226	2.2E-116	2.1787E-131	6.30769684		0.008516701	0.019601821	6.335815362	7.39E-122
Th227	1.8E-04	1.81633E-19	5.90223546		0.109621209	0.038621827	6.050478496	5.89E-10
Th228	3.3E-01	3.2872E-16	5.39930015		0.003074111	0.019010262	5.421384523	9.54E-07
Th229	5.1E-07	5.11833E-22	4.862233245		0.094769364	0.099685142	5.056687752	1.39E-12
Th230	1.7E+00	1.73379E-15	4.67678788		0.001405096	0.012883269	4.691076245	4.36E-06
Th231	1.6E+00	1.60797E-15		0.080038999	0.023548831	0.074878474	0.178466304	1.54E-07
Th232	1.6E+00	1.55721E-15	4.00455		0.001196619	0.010883174	4.016629793	3.35E-06
Th234	1.7E-02	1.71215E-17		0.0433679	0.009067919	0.014136614	0.066572433	6.10E-10
Tl207	1.8E-04	1.82539E-19		0.4932555	0.002169023		0.495424523	4.84E-11
Tl208	2.0E-03	1.97939E-18		0.554863585	3.369590402	0.034133866	3.958587853	4.20E-09
Tl209	1.1E-08	1.05084E-23		1.8248	2.117940734	0.028724369	3.971465102	2.24E-14
Tm170	2.7E-25	2.65672E-40		0.315252	0.005426825	0.014066319	0.334745144	4.76E-32
Tm171	6.6E-12	6.64218E-27		0.0248128	0.000683304	0.000721114	0.026217219	9.33E-20
U232	8.8E-02	8.8251E-17	5.306496425		0.001781837	0.014381205	5.322659468	2.52E-07
U233	4.2E-03	4.22558E-18	4.813433579		0.000718117	0.003004358	4.817156054	1.09E-08
U234	9.9E+02	9.94693E-13	4.763028496		0.001476859	0.011293806	4.775799161	2.54E-03
U235	1.8E+01	1.81903E-14	4.378449		0.153592927	0.041995511	4.574037438	4.46E-05
U236	3.3E+01	3.33559E-14	4.4925232		0.001373011	0.009564051	4.503460262	8.05E-05
U238	3.2E+02	3.22148E-13	4.1940197		0.001212454	0.008504387	4.203736541	7.25E-04
U240	4.2E-09	4.18818E-24		0.125	0.006717716	0.028465325	0.160183041	3.59E-16
Xe127	2.6E-68	2.63427E-83			0.278982226	0.030144757	0.309126983	4.36E-75
Xe131m	4.5E-108	4.4853E-123			0.02009925	0.142249615	0.162348865	3.90E-115
Y90	1.3E+05	1.34525E-10		0.93471862		0.035127416	0.969846036	6.99E-02
Zn65	1.7E-07	1.67979E-22			0.583769699	0.004560562	0.588330261	5.29E-14
Zr93	1.4E+00	1.4275E-15		0.0195			0.0195	1.49E-08
Zr95	4.9E-25	4.87454E-40		0.116123	0.73494917		0.85107217	2.22E-31
<b>Total Absorbed Dose Rate in Rads/Hour</b>								<b>8.36E-01</b>
<b>Total Absorbed Dose For 15 year Operational Life in Rads</b>								<b>1.10E+05</b>

**References:**

a. Disintegration energy based on the total energy reported in the following sources:

Computer software: Radiation Decay Version 3.5 developed by Professor Charles Hacker, Griffith University, Gold Coast, Australia  
Handbook of Health Physics and Radiological Health, 3rd Edition, edited by Bernard Shleien, Lester A. Slaback Jr., and Brian Kent Birkby, Baltimore, Maryland, 1998  
National Nuclear Data Center web site, Decay in the MIRD format, [www.nndc.bnl.gov/nncb/formmird.html](http://www.nndc.bnl.gov/nncb/formmird.html)

b. Total disintegration energy is the sum of alpha, beta, gamma, and electron energies.

## Appendix B-3

### Maximum Allowable Geomembrane Dose Calculation for the Landfill

#### MONTGOMERY WATSON HARZA

Description: Back calculation of maximum allowable concentration for each distinct Parameter.

for the landfill liner

Project #: 2470178

Prepared by: B.G. Adams

Date: 12/5/01

Checked by: J. Pellicer

Date: 12/7/01

#### VARIABLES

Liner Thickness =	60	mils
Liner density =	0.94	g/cm <sup>3</sup>
Depth of leachate =	4	cm

#### CONVERSIONS

pCi/Ci =	1.00E+12
cm <sup>3</sup> /l =	1000
cm/mil =	2.54E-03
(dis/s)/Ci =	3.70E+10
sec/hr =	3600
g/kg =	1.00E+03
eV/Mev =	1.00E+06
J/eV =	1.60E-19
rad/Gy =	100

15 yr Dose = 1.0E+06  
Daily Dose = 1.8E+02  
Dose Rad/hr = 7.6E+00

Constituent	ICDF Maximum Allowable Activity Concentration (pCi/L)	ICDF Maximum Allowable Activity Concentration (Ci/cm <sup>3</sup> )	Disintegration Energy (MeV/dis)	ICDF Liner Absorbed Dose (Rads/hr)
Ac225	2.2E+07	2.19282E-08	5.832179811	7.61E+00
Ac227	1.6E+09	1.60601E-06	0.079631727	7.61E+00
Ac228	9.4E+07	9.43018E-08	1.356167107	7.61E+00
Ag108	2.0E+08	2.03876E-07	0.627288369	7.61E+00
Ag108m	7.8E+07	7.82796E-08	1.63374702	7.61E+00
Ag109m	1.5E+09	1.47066E-06	0.086960304	7.61E+00
Ag110	1.1E+08	1.05513E-07	1.212069842	7.61E+00
Ag110m	4.6E+07	4.55319E-08	2.808781272	7.61E+00
Am241	2.3E+07	2.3105E-08	5.535129217	7.61E+00
Am242	6.7E+08	6.67823E-07	0.191501428	7.61E+00
Am242m	1.9E+09	1.94784E-06	0.065656838	7.61E+00
Am243	2.4E+07	2.39129E-08	5.348125195	7.61E+00
Am246	1.0E+08	1.0077E-07	1.269116692	7.61E+00
At217	1.8E+07	1.81E-08	7.065707158	7.61E+00
Ba137m	1.9E+08	1.93343E-07	0.661462561	7.61E+00
Be 10	6.3E+08	6.31551E-07	0.2025	7.61E+00
Bi210	3.3E+08	3.28764E-07	0.389	7.61E+00
Bi211	1.9E+07	1.93584E-08	6.606380966	7.61E+00
Bi214	5.9E+07	5.93826E-08	2.153646154	7.61E+00
Bk249	3.9E+09	3.87546E-06	0.03299967	7.61E+00
Bk250	1.1E+08	1.08372E-07	1.180096454	7.61E+00
Cd109	6.5E+09	6.51113E-06	0.019641609	7.61E+00
Cd113m	6.9E+08	6.89959E-07	0.185357358	7.61E+00
Ce141	5.2E+08	5.18446E-07	0.246677795	7.61E+00
Ce144	1.1E+09	1.14377E-06	0.111813852	7.61E+00
Cf249	2.1E+07	2.06215E-08	6.201740977	7.61E+00

Constituent	ICDF Maximum Allowable Activity Concentration (pCi/L)	ICDF Maximum Allowable Activity Concentration (Ci/cm <sup>3</sup> )	Disintegration Energy (MeV/dis)	ICDF Liner Absorbed Dose (Rads/hr)
Cf250	2.1E+07	2.12255E-08	6.025256294	7.61E+00
Cf251	2.2E+07	2.15157E-08	5.94399266	7.61E+00
Cm241	7.5E+08	7.47015E-07	0.1712	7.61E+00
Cm242	2.1E+07	2.08953E-08	6.120469416	7.61E+00
Cm243	2.1E+07	2.10012E-08	6.089596726	7.61E+00
Cm244	2.2E+07	2.2033E-08	5.804428351	7.61E+00
Cm245	2.3E+07	2.32214E-08	5.507387757	7.61E+00
Cm246	2.4E+07	2.3758E-08	5.382991049	7.61E+00
Cm247	2.4E+07	2.42268E-08	5.278828648	7.61E+00
Cm248	2.7E+07	2.74562E-08	4.657924475	7.61E+00
Co-57	8.9E+08	8.91938E-07	0.143383365	7.61E+00
Co-58	1.3E+08	1.30589E-07	0.979328243	7.61E+00
Co-60	4.9E+07	4.91578E-08	2.601603093	7.61E+00
Cr-51	3.5E+09	3.5337E-06	0.036191289	7.61E+00
Cs-134	7.4E+07	7.44797E-08	1.717100005	7.61E+00
Cs135	2.3E+09	2.27156E-06	0.0563	7.61E+00
Cs137	7.5E+08	7.48968E-07	0.1707536	7.61E+00
Eu150	4.4E+08	4.37976E-07	0.292	7.61E+00
Eu152	1.0E+08	1.00204E-07	1.276280952	7.61E+00
Eu154	8.4E+07	8.37567E-08	1.526910861	7.61E+00
Eu155	1.0E+09	1.04509E-06	0.122371015	7.61E+00
Fe-59	9.8E+07	9.79309E-08	1.30591073	7.61E+00
Fr221	2.0E+07	2E-08	6.394459322	7.61E+00
Fr223	2.9E+08	2.94183E-07	0.434726751	7.61E+00
Gd153	8.4E+08	8.39442E-07	0.15235	7.61E+00
H 3	2.2E+10	2.24959E-05	0.005685	7.61E+00
Ho166m	7.3E+07	7.34449E-08	1.741292443	7.61E+00
In114	1.6E+08	1.5914E-07	0.803627157	7.61E+00
In114m	5.3E+08	5.34236E-07	0.239386934	7.61E+00
In115	8.4E+08	8.41375E-07	0.152	7.61E+00
K-40	2.1E+08	2.09528E-07	0.610365806	7.61E+00
La140	4.5E+07	4.48906E-08	2.848903435	7.61E+00
Mn-54	1.5E+08	1.52281E-07	0.839824907	7.61E+00
Nb92	8.5E+07	8.46967E-08	1.509964777	7.61E+00
Nb93m	4.2E+09	4.22739E-06	0.030252491	7.61E+00
Nb94	7.4E+07	7.43255E-08	1.720660307	7.61E+00
Nb95m	5.2E+08	5.182E-07	0.24679489	7.61E+00
Nd144	6.7E+07	6.731E-08	1.9	7.61E+00
Np236	3.7E+08	3.74982E-07	0.341053651	7.61E+00
Np239	3.1E+08	3.0787E-07	0.415400022	7.61E+00
Np240m	1.3E+08	1.34777E-07	0.948896841	7.61E+00

Constituent	ICDF Maximum Allowable Activity Concentration (pCi/L)	ICDF Maximum Allowable Activity Concentration (Ci/cm <sup>3</sup> )	Disintegration Energy (MeV/dis)	ICDF Liner Absorbed Dose (Rads/hr)
Pa231	2.3E+07	2.34508E-08	5.453502195	7.61E+00
Pa233	3.1E+08	3.12304E-07	0.409501364	7.61E+00
Pa234	5.2E+07	5.19138E-08	2.463486522	7.61E+00
Pa234m	1.5E+08	1.53191E-07	0.834833438	7.61E+00
Pb209	6.5E+08	6.47212E-07	0.1976	7.61E+00
Pb210	3.3E+09	3.28775E-06	0.038898656	7.61E+00
Pb212	4.0E+08	3.98103E-07	0.321245808	7.61E+00
Pb214	2.4E+08	2.37504E-07	0.538471991	7.61E+00
Pd107	3.9E+09	3.8636E-06	0.033101	7.61E+00
Pm146	1.5E+08	1.50311E-07	0.850831344	7.61E+00
Pm147	2.1E+09	2.06401E-06	0.061961344	7.61E+00
Pm148	9.8E+07	9.83065E-08	1.30092091	7.61E+00
Pm148m	5.9E+07	5.93369E-08	2.155301698	7.61E+00
Po210	2.4E+07	2.41095E-08	5.304505553	7.61E+00
Po211	1.7E+07	1.71656E-08	7.450314354	7.61E+00
Po212	1.5E+07	1.45578E-08	8.7849	7.61E+00
Po213	1.5E+07	1.52667E-08	8.376999781	7.61E+00
Po214	1.7E+07	1.66369E-08	7.687067933	7.61E+00
Po215	1.7E+07	1.73143E-08	7.38630707	7.61E+00
Po216	1.9E+07	1.88669E-08	6.778486648	7.61E+00
Po218	2.1E+07	2.13102E-08	6.001296466	7.61E+00
Pr144	1.0E+08	9.96007E-08	1.284017776	7.61E+00
Pr144m	1.1E+10	1.07948E-05	0.01184728	7.61E+00
Pu236	2.2E+07	2.21579E-08	5.771712409	7.61E+00
Pu237	2.1E+09	2.05474E-06	0.062241073	7.61E+00
Pu238	2.3E+07	2.32653E-08	5.496995126	7.61E+00
Pu239	2.5E+07	2.48158E-08	5.153526936	7.61E+00
Pu240	2.5E+07	2.47641E-08	5.164286359	7.61E+00
Pu241	2.4E+10	2.44535E-05	0.005229895	7.61E+00
Pu242	2.6E+07	2.59776E-08	4.923056772	7.61E+00
Pu243	6.6E+08	6.55155E-07	0.195204338	7.61E+00
Pu244	2.8E+07	2.78131E-08	4.598152374	7.61E+00
Pu246	8.3E+08	8.27667E-07	0.154517541	7.61E+00
Ra222	2.0E+07	1.95145E-08	6.553547823	7.61E+00
Ra224	2.2E+07	2.24876E-08	5.687100654	7.61E+00
Ra225	1.1E+09	1.07266E-06	0.119225863	7.61E+00
Ra226	2.7E+07	2.67009E-08	4.789685685	7.61E+00
Ra228	1.1E+10	1.10554E-05	0.011568007	7.61E+00
Rb87	1.6E+09	1.62296E-06	0.0788	7.61E+00
Rh102	1.6E+09	1.60262E-06	0.0798	7.61E+00
Rh103m	3.3E+09	3.29095E-06	0.038860869	7.61E+00

Constituent	ICDF Maximum Allowable Activity Concentration (pCi/L)	ICDF Maximum Allowable Activity Concentration (Ci/cm <sup>3</sup> )	Disintegration Energy (MeV/dis)	ICDF Liner Absorbed Dose (Rads/hr)
Rh106	7.9E+07	7.89747E-08	1.61936774	7.61E+00
Rn218	1.8E+07	1.79292E-08	7.132996084	7.61E+00
Rn219	1.9E+07	1.87184E-08	6.832252476	7.61E+00
Rn220	2.0E+07	2.03376E-08	6.288297183	7.61E+00
Rn222	2.3E+07	2.32966E-08	5.48961137	7.61E+00
Ru103	2.3E+08	2.31026E-07	0.553570714	7.61E+00
Ru106	3.2E+09	3.24583E-06	0.039401	7.61E+00
Sb124	5.7E+07	5.68644E-08	2.249015659	7.61E+00
Sb125	2.4E+08	2.41207E-07	0.530203897	7.61E+00
Sb126	4.2E+07	4.18972E-08	3.052446696	7.61E+00
Sc-46	6.0E+07	6.0283E-08	2.121478487	7.61E+00
Se 79	2.4E+09	2.44998E-06	0.0522	7.61E+00
Sm146	5.1E+07	5.0549E-08	2.53	7.61E+00
Sm147	5.7E+07	5.69003E-08	2.2476	7.61E+00
Sm148	6.4E+07	6.42658E-08	1.99	7.61E+00
Sm151	6.5E+09	6.46392E-06	0.019785044	7.61E+00
Sn119m	6.5E+09	6.46392E-06	0.019785044	7.61E+00
Sn121m	1.5E+09	1.46829E-06	0.087100885	7.61E+00
Sn123	4.2E+10	4.20688E-05	0.00304	7.61E+00
Sn126	2.4E+08	2.4248E-07	0.527419926	7.61E+00
Sr89	3.6E+08	3.56646E-07	0.358587622	7.61E+00
Sr90	2.2E+08	2.19335E-07	0.583077055	7.61E+00
Tb160	2.3E+08	2.34229E-07	0.546	7.61E+00
Tc 98	9.5E+07	9.4532E-08	1.352864583	7.61E+00
Tc 99	8.4E+07	8.43962E-08	1.515340293	7.61E+00
Te123	1.5E+09	1.51168E-06	0.084600538	7.61E+00
Te123m	7.5E+09	7.49405E-06	0.017065401	7.61E+00
Te127	8.0E+08	8.02321E-07	0.159398912	7.61E+00
Te127m	1.4E+09	1.40818E-06	0.090818471	7.61E+00
Te129	1.4E+09	1.40818E-06	0.090818471	7.61E+00
Th226	4.1E+08	4.14391E-07	0.308619356	7.61E+00
Th227	2.0E+07	2.01851E-08	6.335815362	7.61E+00
Th228	2.1E+07	2.1137E-08	6.050478496	7.61E+00
Th229	2.4E+07	2.35897E-08	5.421384523	7.61E+00
Th230	2.5E+07	2.52911E-08	5.056687752	7.61E+00
Th231	2.7E+07	2.72622E-08	4.691076245	7.61E+00
Th232	7.2E+08	7.166E-07	0.178466304	7.61E+00
Th234	3.2E+07	3.18399E-08	4.016629793	7.61E+00
Tl207	1.9E+09	1.92105E-06	0.066572433	7.61E+00
Tl208	2.6E+08	2.5814E-07	0.495424523	7.61E+00
Tl209	3.2E+07	3.23067E-08	3.958587853	7.61E+00

Constituent	ICDF Maximum Allowable Activity Concentration (pCi/L)	ICDF Maximum Allowable Activity Concentration (Ci/cm <sup>3</sup> )	Disintegration Energy (MeV/dis)	ICDF Liner Absorbed Dose (Rads/hr)
Tm170	3.2E+07	3.2202E-08	3.971465102	7.61E+00
Tm171	3.8E+08	3.82049E-07	0.334745144	7.61E+00
U232	4.9E+09	4.87805E-06	0.026217219	7.61E+00
U233	2.4E+07	2.40273E-08	5.322659468	7.61E+00
U234	2.7E+07	2.65487E-08	4.817156054	7.61E+00
U235	2.7E+07	2.67786E-08	4.775799161	7.61E+00
U236	2.8E+07	2.79598E-08	4.574037438	7.61E+00
U238	2.8E+07	2.83979E-08	4.503460262	7.61E+00
U240	3.0E+07	3.04227E-08	4.203736541	7.61E+00
Xe127	8.0E+08	7.98393E-07	0.160183041	7.61E+00
Xe131m	4.1E+08	4.1371E-07	0.309126983	7.61E+00
Y90	7.9E+08	7.87742E-07	0.162348865	7.61E+00
Zn65	1.3E+08	1.31865E-07	0.969846036	7.61E+00
Zr93	2.2E+08	2.17376E-07	0.588330261	7.61E+00
Zr95	6.6E+09	6.55841E-06	0.0195	7.61E+00

## Appendix B-4

### Geomembrane Maximum Allowable Dose in the Evaporation Pond

MONTGOMERY WATSON HARZA

Description: Back calculation of maximum allowable concentration for each distinct Parameter for the evaporation ponds

Project #: 2470178

Prepared by: B.G. Adams

Date: 12/5/01

Checked by: J. Pellicer

Date: 12/7/01

#### VARIABLES

Liner Thickness = 60 mils  
Liner density = 0.94 g/cm<sup>3</sup>  
Depth of leachate = 36 cm

#### CONVERSIONS

15 yr Dose = 1,000,000 pCi/Ci = 1.00E+12  
Daily Dose = 182.6484018 cm<sup>3</sup>/l = 1000  
Dose Rad/hr = 7.610350076 cm/mil = 2.54E-03  
(dis/s)/Ci = 3.70E+10 sec/hr = 3600  
g/kg = 1.00E+03 eV/Mev = 1.00E+06  
J/eV = 1.60E-19 rad/Gy = 100

Constituent	ICDF Maximum Activity Concentration (pCi/l)	ICDF Maximum Activity Concentration (Ci/cm <sup>3</sup> )	Dissintegration Energy (MeV/dis)	ICDF Liner Radiation Dose (Rads/hr)
Ac225	2.4E+06	2.43646E-09	5.832179811	7.61E+00
Ac227	1.8E+08	1.78445E-07	0.079631727	7.61E+00
Ac228	1.0E+07	1.0478E-08	1.356167107	7.61E+00
Ag108	2.3E+07	2.26529E-08	0.627288369	7.61E+00
Ag108m	8.7E+06	8.69773E-09	1.63374702	7.61E+00
Ag109m	1.6E+08	1.63407E-07	0.086960304	7.61E+00
Ag110	1.2E+07	1.17237E-08	1.212069842	7.61E+00
Ag110m	5.1E+06	5.05909E-09	2.808781272	7.61E+00
Am241	2.6E+06	2.56722E-09	5.535129217	7.61E+00
Am242	7.4E+07	7.42025E-08	0.191501428	7.61E+00
Am242m	2.2E+08	2.16427E-07	0.065656838	7.61E+00
Am243	2.7E+06	2.65699E-09	5.348125195	7.61E+00
Am246	1.1E+07	1.11967E-08	1.269116692	7.61E+00
At217	2.0E+06	2.01111E-09	7.065707158	7.61E+00
Ba137m	2.1E+07	2.14825E-08	0.661462561	7.61E+00
Be 10	7.0E+07	7.01723E-08	0.2025	7.61E+00
Bi210	3.7E+07	3.65293E-08	0.389	7.61E+00
Bi211	2.2E+06	2.15093E-09	6.606380966	7.61E+00
Bi214	6.6E+06	6.59806E-09	2.153646154	7.61E+00
Bk249	4.3E+08	4.30607E-07	0.03299967	7.61E+00
Bk250	1.2E+07	1.20413E-08	1.180096454	7.61E+00
Cd109	7.2E+08	7.23459E-07	0.019641609	7.61E+00
Cd113m	7.7E+07	7.66621E-08	0.185357358	7.61E+00
Ce141	5.8E+07	5.76051E-08	0.246677795	7.61E+00
Ce144	1.3E+08	1.27085E-07	0.111813852	7.61E+00
Cf249	2.3E+06	2.29127E-09	6.201740977	7.61E+00

Constituent	ICDF Maximum Activity Concentration (pCi/l)	ICDF Maximum Activity Concentration (Ci/cm <sup>3</sup> )	Dissintegration Energy (MeV/dis)	ICDF Liner Radiation Dose (Rads/hr)
Cf250	2.4E+06	2.35839E-09	6.025256294	7.61E+00
Cf251	2.4E+06	2.39063E-09	5.94399266	7.61E+00
Cm241	8.3E+07	8.30017E-08	0.1712	7.61E+00
Cm242	2.3E+06	2.3217E-09	6.120469416	7.61E+00
Cm243	2.3E+06	2.33347E-09	6.089596726	7.61E+00
Cm244	2.4E+06	2.44811E-09	5.804428351	7.61E+00
Cm245	2.6E+06	2.58015E-09	5.507387757	7.61E+00
Cm246	2.6E+06	2.63978E-09	5.382991049	7.61E+00
Cm247	2.7E+06	2.69186E-09	5.278828648	7.61E+00
Cm248	3.1E+06	3.05069E-09	4.657924475	7.61E+00
Co-57	9.9E+07	9.91042E-08	0.143383365	7.61E+00
Co-58	1.5E+07	1.45098E-08	0.979328243	7.61E+00
Co-60	5.5E+06	5.46197E-09	2.601603093	7.61E+00
Cr-51	3.9E+08	3.92633E-07	0.036191289	7.61E+00
Cs-134	8.3E+06	8.27552E-09	1.717100005	7.61E+00
Cs135	2.5E+08	2.52396E-07	0.0563	7.61E+00
Cs137	8.3E+07	8.32187E-08	0.1707536	7.61E+00
Eu150	4.9E+07	4.8664E-08	0.292	7.61E+00
Eu152	1.1E+07	1.11338E-08	1.276280952	7.61E+00
Eu154	9.3E+06	9.3063E-09	1.526910861	7.61E+00
Eu155	1.2E+08	1.16121E-07	0.122371015	7.61E+00
Fe-59	1.1E+07	1.08812E-08	1.30591073	7.61E+00
Fr221	2.2E+06	2.22222E-09	6.394459322	7.61E+00
Fr223	3.3E+07	3.26869E-08	0.434726751	7.61E+00
Gd153	9.3E+07	9.32714E-08	0.15235	7.61E+00
H 3	2.5E+09	2.49954E-06	0.005685	7.61E+00
Ho166m	8.2E+06	8.16054E-09	1.741292443	7.61E+00
In114	1.8E+07	1.76822E-08	0.803627157	7.61E+00
In114m	5.9E+07	5.93595E-08	0.239386934	7.61E+00
In115	9.3E+07	9.34861E-08	0.152	7.61E+00
K-40	2.3E+07	2.32809E-08	0.610365806	7.61E+00
La140	5.0E+06	4.98785E-09	2.848903435	7.61E+00
Mn-54	1.7E+07	1.69201E-08	0.839824907	7.61E+00
Nb92	9.4E+06	9.41074E-09	1.509964777	7.61E+00
Nb93m	4.7E+08	4.6971E-07	0.030252491	7.61E+00
Nb94	8.3E+06	8.25839E-09	1.720660307	7.61E+00
Nb95m	5.8E+07	5.75777E-08	0.24679489	7.61E+00
Nd144	7.5E+06	7.47889E-09	1.9	7.61E+00
Np236	4.2E+07	4.16647E-08	0.341053651	7.61E+00
Np239	3.4E+07	3.42077E-08	0.415400022	7.61E+00
Np240m	1.5E+07	1.49752E-08	0.948896841	7.61E+00

Constituent	ICDF Maximum Activity Concentration (pCi/l)	ICDF Maximum Activity Concentration (Ci/cm <sup>3</sup> )	Dissintegration Energy (MeV/dis)	ICDF Liner Radiation Dose (Rads/hr)
Pa231	2.6E+06	2.60565E-09	5.453502195	7.61E+00
Pa233	3.5E+07	3.47005E-08	0.409501364	7.61E+00
Pa234	5.8E+06	5.7682E-09	2.463486522	7.61E+00
Pa234m	1.7E+07	1.70212E-08	0.834833438	7.61E+00
Pb209	7.2E+07	7.19124E-08	0.1976	7.61E+00
Pb210	3.7E+08	3.65305E-07	0.038898656	7.61E+00
Pb212	4.4E+07	4.42337E-08	0.321245808	7.61E+00
Pb214	2.6E+07	2.63893E-08	0.538471991	7.61E+00
Pd107	4.3E+08	4.29289E-07	0.033101	7.61E+00
Pm146	1.7E+07	1.67012E-08	0.850831344	7.61E+00
Pm147	2.3E+08	2.29335E-07	0.061961344	7.61E+00
Pm148	1.1E+07	1.09229E-08	1.30092091	7.61E+00
Pm148m	6.6E+06	6.59299E-09	2.155301698	7.61E+00
Po210	2.7E+06	2.67883E-09	5.304505553	7.61E+00
Po211	1.9E+06	1.90729E-09	7.450314354	7.61E+00
Po212	1.6E+06	1.61754E-09	8.7849	7.61E+00
Po213	1.7E+06	1.6963E-09	8.376999781	7.61E+00
Po214	1.8E+06	1.84855E-09	7.687067933	7.61E+00
Po215	1.9E+06	1.92382E-09	7.38630707	7.61E+00
Po216	2.1E+06	2.09632E-09	6.778486648	7.61E+00
Po218	2.4E+06	2.3678E-09	6.001296466	7.61E+00
Pr144	1.1E+07	1.10667E-08	1.284017776	7.61E+00
Pr144m	1.2E+09	1.19942E-06	0.01184728	7.61E+00
Pu236	2.5E+06	2.46199E-09	5.771712409	7.61E+00
Pu237	2.3E+08	2.28304E-07	0.062241073	7.61E+00
Pu238	2.6E+06	2.58503E-09	5.496995126	7.61E+00
Pu239	2.8E+06	2.75731E-09	5.153526936	7.61E+00
Pu240	2.8E+06	2.75157E-09	5.164286359	7.61E+00
Pu241	2.7E+09	2.71705E-06	0.005229895	7.61E+00
Pu242	2.9E+06	2.8864E-09	4.923056772	7.61E+00
Pu243	7.3E+07	7.2795E-08	0.195204338	7.61E+00
Pu244	3.1E+06	3.09035E-09	4.598152374	7.61E+00
Pu246	9.2E+07	9.1963E-08	0.154517541	7.61E+00
Ra222	2.2E+06	2.16827E-09	6.553547823	7.61E+00
Ra224	2.5E+06	2.49862E-09	5.687100654	7.61E+00
Ra225	1.2E+08	1.19185E-07	0.119225863	7.61E+00
Ra226	3.0E+06	2.96677E-09	4.789685685	7.61E+00
Ra228	1.2E+09	1.22838E-06	0.011568007	7.61E+00
Rb87	1.8E+08	1.80329E-07	0.0788	7.61E+00
Rh102	1.8E+08	1.78069E-07	0.0798	7.61E+00
Rh103m	3.7E+08	3.65661E-07	0.038860869	7.61E+00

Constituent	ICDF Maximum Activity Concentration (pCi/l)	ICDF Maximum Activity Concentration (Ci/cm <sup>3</sup> )	Dissintegration Energy (MeV/dis)	ICDF Liner Radiation Dose (Rads/hr)
Rh106	8.8E+06	8.77496E-09	1.61936774	7.61E+00
Rn218	2.0E+06	1.99213E-09	7.132996084	7.61E+00
Rn219	2.1E+06	2.07983E-09	6.832252476	7.61E+00
Rn220	2.3E+06	2.25974E-09	6.288297183	7.61E+00
Rn222	2.6E+06	2.58851E-09	5.48961137	7.61E+00
Ru103	2.6E+07	2.56695E-08	0.553570714	7.61E+00
Ru106	3.6E+08	3.60648E-07	0.039401	7.61E+00
Sb124	6.3E+06	6.31827E-09	2.249015659	7.61E+00
Sb125	2.7E+07	2.68008E-08	0.530203897	7.61E+00
Sb126	4.7E+06	4.65525E-09	3.052446696	7.61E+00
Sc-46	6.7E+06	6.69811E-09	2.121478487	7.61E+00
Se 79	2.7E+08	2.7222E-07	0.0522	7.61E+00
Sm146	5.6E+06	5.61656E-09	2.53	7.61E+00
Sm147	6.3E+06	6.32225E-09	2.2476	7.61E+00
Sm148	7.1E+06	7.14065E-09	1.99	7.61E+00
Sm151	7.2E+08	7.18214E-07	0.019785044	7.61E+00
Sn119m	7.2E+08	7.18214E-07	0.019785044	7.61E+00
Sn121m	1.6E+08	1.63143E-07	0.087100885	7.61E+00
Sn123	4.7E+09	4.67431E-06	0.00304	7.61E+00
Sn126	2.7E+07	2.69423E-08	0.527419926	7.61E+00
Sr89	4.0E+07	3.96274E-08	0.358587622	7.61E+00
Sr90	2.4E+07	2.43705E-08	0.583077055	7.61E+00
Tb160	2.6E+07	2.60254E-08	0.546	7.61E+00
Tc 98	1.1E+07	1.05036E-08	1.352864583	7.61E+00
Tc 99	9.4E+06	9.37736E-09	1.515340293	7.61E+00
Te123	1.7E+08	1.67965E-07	0.084600538	7.61E+00
Te123m	8.3E+08	8.32673E-07	0.017065401	7.61E+00
Te127	8.9E+07	8.91467E-08	0.159398912	7.61E+00
Te127m	6.2E+07	6.23836E-08	0.227782297	7.61E+00
Te129	1.6E+08	1.56465E-07	0.090818471	7.61E+00
Th226	4.6E+07	4.60434E-08	0.308619356	7.61E+00
Th227	2.2E+06	2.24279E-09	6.335815362	7.61E+00
Th228	2.3E+06	2.34856E-09	6.050478496	7.61E+00
Th229	2.6E+06	2.62108E-09	5.421384523	7.61E+00
Th230	2.8E+06	2.81012E-09	5.056687752	7.61E+00
Th231	3.0E+06	3.02913E-09	4.691076245	7.61E+00
Th232	8.0E+07	7.96223E-08	0.178466304	7.61E+00
Th234	3.5E+06	3.53776E-09	4.016629793	7.61E+00
Tl207	2.1E+08	2.1345E-07	0.066572433	7.61E+00
Tl208	2.9E+07	2.86823E-08	0.495424523	7.61E+00
Tl209	3.6E+06	3.58964E-09	3.958587853	7.61E+00

Constituent	ICDF Maximum Activity Concentration (pCi/l)	ICDF Maximum Activity Concentration (Ci/cm <sup>3</sup> )	Dissintegration Energy (MeV/dis)	ICDF Liner Radiation Dose (Rads/hr)
Tm170	3.6E+06	3.578E-09	3.971465102	7.61E+00
Tm171	4.2E+07	4.24499E-08	0.334745144	7.61E+00
U232	5.4E+08	5.42006E-07	0.026217219	7.61E+00
U233	2.7E+06	2.6697E-09	5.322659468	7.61E+00
U234	2.9E+06	2.94985E-09	4.817156054	7.61E+00
U235	3.0E+06	2.9754E-09	4.775799161	7.61E+00
U236	3.1E+06	3.10664E-09	4.574037438	7.61E+00
U238	3.2E+06	3.15533E-09	4.503460262	7.61E+00
U240	3.4E+06	3.3803E-09	4.203736541	7.61E+00
Xe127	8.9E+07	8.87103E-08	0.160183041	7.61E+00
Xe131m	4.6E+07	4.59678E-08	0.309126983	7.61E+00
Y90	8.8E+07	8.75269E-08	0.162348865	7.61E+00
Zn65	2.3E+07	2.34524E-08	0.605903	7.61E+00
Zr93	2.4E+07	2.41529E-08	0.588330261	7.61E+00
Zr95	7.3E+08	7.28712E-07	0.0195	7.61E+00

431.02  
01/30/2003  
Rev. 11

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## **Appendix C**

### **Manufacturers Maximum Constituent Concentration Data for HDPE Geomembrane**

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## Appendix C

# Manufacturers Maximum Constituent Concentration Data for HDPE Geomembrane

### HDPE Liner Manufacturer's Compatibility Data

#### LINER COMPATIBILITY

1. Identify the manufacturer and the type of liner that will be used in the landfill which will contain the form R wastes.

MANUFACTURER: GSE Lining Technology, Inc.  
LINER TYPE: 60 mil HDPE

2. Describe how the following types of chemicals will affect the liner to be used to contain the form R waste:

aromatic halogenated hydrocarbons - SEE ATTACHED SHEET

aliphatic halogenated hydrocarbons - SEE ATTACHED SHEET

aromatic hydrocarbons - SEE ATTACHED SHEET

aliphatic hydrocarbons - SEE ATTACHED SHEET

volatile and semi-volatile organics - SEE ATTACHED SHEET

oil and grease - SEE ATTACHED SHEET

strong oxidizers - GENERALLY NO SIGNIFICANT EFFECT

acids - GENERALLY NO SIGNIFICANT EFFECT

bases - GENERALLY NO SIGNIFICANT EFFECT

dissolved metals, salts and nutrients - GENERALLY NO EFFECT

3. Give an acceptable compatibility limit for each of the compounds on the following pages and certificate liner manufacturer:

*Signature of Liner Manufacturer:*

---

Matthew W. Adams  
Technical Support Chemist

---

Date

**Aromatic Halogenated Hydrocarbons**

Aromatic Halogenated Hydrocarbons tend to be absorbed into polyethylene over long periods of time where they may function as a plasticizer. As a result, the polyethylene may swell and become softer and more elastic. These effects are generally reversible if the exposure is terminated.

Since polyethylene consists of a range of molecular weight molecules and somewhat different branching arrangements, some lower density polyethylenes may contain fractions that are extractable. Some types of chemical stabilizers and processing aids may also be extractable.

These above noted effects increase with increasing temperature. Softening, swelling and increased elasticity may rapidly reduce the usefulness of polyethylene as a structural component such as for use as a pressure pipe. Generally, these effects do not seriously affect the performance of polyethylene as a containment membrane.

GSE HyperFlex® polyethylene geomembranes are manufactured from a narrow molecular weight range resin designed to minimize the possibility of extractable fractions and maximize the resistance to stress cracking.

**Aliphatic Halogenated Hydrocarbons**

Similar effects as for Aromatic Halogenated Hydrocarbons but generally less severe. Some materials have little or no effect.

**Aromatic Hydrocarbons**

Again similar to Aromatic Halogenated Hydrocarbons but generally less severe. Many materials have no significant effect.

**Aliphatic Hydrocarbons**

Again similar, but with further reductions of general severity. Most materials have no significant effect.

**Volatile and Semivolatile Organics**

These are mostly covered by the previously noted comments about hydrocarbons.

**Oil and Grease**

Mineral, vegetable and animal oils, fats or grease generally have no significant effect.

**Strong Oxidizers** - Generally no significant effect.

**Acids** - Generally no significant effect.

**Dissolved Metals, Salts and Nutrients** - Generally no effect.

FORM R  
LINER COMPATABILITY

PARAMETER CLASSIFICATION	PARAMETER	MANUFACTURER'S LINER/LEACHATE LIMIT mg/l	
Aromatic	polychlorinated biphenyl	(	2000 )
Halogenated	aldrin	(	2000 )
Hydrocarbons	dichlorobenzene	(	2000 )
	hexachlorobenzene	(	2000 )
	pentachlorobenzene	(	2000 )
	trichlorobenzene	(	2000 )
	tetrachlorobenzene	(	2000 )
	2-chloronaphthalene	(	2000 )
	chloronaphthalene	(	2000 )
	chlorobenzene	(	2000 )
	4,4-DDT	(	2000 )
	4,4-DDE	(	2000 )
	4,4-DDD	(	2000 )
Aliphatic	bromoform	(	2000 )
Halogenated	carbon tetrachloride	(	2000 )
Hydrocarbons	chlorodibromomethane	(	2000 )
	chloroethane	(	2000 )
	chloroform	(	2000 )
	dichlorobromomethane	(	2000 )
	dichlorodifluoromethane	(	2000 )
	dichloroethane	(	2000 )
	dichloropropane	(	2000 )
	dichloroethene	(	2000 )
	ethylene chloride	(	2000 )
	ethylene dichloride	(	2000 )
	hexachloroethane	(	2000 )
	methyl bromide	(	2000 )
	methyl chloride	(	2000 )
	methylene chloride	(	2000 )
	tetrachloroethane	(	2000 )
	tetrachloroethene	(	2000 )
	trichloroethane	(	2000 )
	trichloroethene	(	2000 )
	trichlorofluoromethane	(	2000 )
	v vinyl chloride	(	2000 )

TEMPERATURE 70 °F

FORM R

LINER COMPATABILITY

PARAMETER CLASSIFICATION	PARAMETER	MANUFACTURER'S LINER/LEACHATE LIMIT mg/l
Aromatic Hydrocarbons	acenaphthene	( 2000 )
	acenaphthylene	( 2000 )
	anthracene	( 2000 )
	benzene	( 2000 )
	benzo(a)anthracene	( 2000 )
	benzo(a)pyrene	( 2000 )
	benzo(g,h,i)perylene	( 2000 )
	benzo(k)fluoranthene	( 2000 )
	3,4-benzofluoranthene	( 2000 )
	chrysene	( 2000 )
	dibenzo(a,h)anthracene	( 2000 )
	ethyl benzene	( 2000 )
	flouranthene	( 2000 )
	flourene	( 2000 )
	ideno(1,2,3,c,d)pyrene	( 2000 )
	naphthalene	( 2000 )
	phenanthrene	( 2000 )
	pyrene	( 2000 )
	styrene	( 5000 )
	toluene	( 5000 )
	xylene	( 5000 )
Aliphatic Hydrocarbons	heptane	( 500,000 )
	hexane	( 500,000 )
	octane	( 500,000 )

TEMPERATURE 70 °F

FORM R  
LINER COMPATABILITY

PARAMETER CLASSIFICATION	PARAMETER	MANUFACTURER'S LINER/LEACHATE LIMIT mg/l
Volatile &	acrolein	( 200,000 )
Semivolatile	acrylonitrile	( 200,000 )
Organics	acetone	( 200,000 )
	amyl acetate	( 200,000 )
	benzidine	( 200,000 )
	butyl alcohol	( 500,000 )
	bis(2-chloroethoxy)methane	( 2,000 )
	bis(2-chloroethoxy)ether	( 2,000 )
	bis(2-chloroisopropyl)ether	( 2,000 )
	bis(2-ethylhexyl)phthalate	( 2,000 )
	4-bromophenyl phenyl ether	( 2,000 )
	butyl benzyl phthalate	( 200,000 )
	cresol	( 100,000 )
	chlordan	( 2,000 )
	alpha-BHC	( 2,000 )
	beta-BHC	( 2,000 )
	gamma-BHC	( 2,000 )
	delta-BHC	( 2,000 )
	dieldrin	( 2,000 )
	dichlorobenzidine	( 2,000 )
	diethyl phthalate	( 100,000 )
	dibutyl phthalate	( 100,000 )
	dimethyl phthalate	( 100,000 )
	isobutyl alcohol	( 500,000 )
	isopropyl alcohol	( 500,000 )
	methyl alcohol	( 500,000 )
	2-chloroethyl vinyl ether	( 2,000 )
	2-chlorophenol	( 2,000 )
	dichlorophenol	( 2,000 )
	dimethyl phenol	( 2,000 )
	dinitro-o-cresol	( 2,000 )
	dinitrophenol	( 2,000 )
	dinitrotoluene	( 2,000 )
	diphenylhydrazine	( 2,000 )
	ethyl acetate	( 100,000 )
	ethyl ether	( 2,000 )
	ethyl glycol	( 500,000 )
	endosulfan	( 2,000 )
	endrin	( 2,000 )
	formaldehyde	( 200,000 )
	heptachlor	( 2,000 )
	hexachlorocyclopentadiene	( 2,000 )
	hexachlorobutadiene	( 2,000 )
	isophorone	( 2,000 )
	methyl ethyl ketone	( 200,000 )

TEMPERATURE 70 °F

FORM R  
LINER COMPATABILITY

PARAMETER CLASSIFICATION	PARAMETER	MANUFACTURER'S LINER/LEACHATE LIMIT mg/l	
Volatile & Semivolatile Organics (cont.)	methyl isobutyl ketone	(	500,000 )
	nitrophenol	(	100,000 )
	N-nitrosodimethylamine	(	100,000 )
	N-nitrosodi-n-propylamine	(	100,000 )
	nitrobenzene	(	100,000 )
	pentachlorophenol	(	100,000 )
	phenol	(	100,000 )
	pyridine	(	100,000 )
	toxaphene	(	100,000 )
	trichlorophenol	(	100,000 )
	2,4,5-TP(silvex)	(	? )

TEMPERATURE 70 °F

FORM R  
LINER COMPATABILITY

PARAMETER CLASSIFICATION	PARAMETER	MANUFACTURER'S LINER/LEACHATE LIMIT mg/l
Acids & Bases	acetic acid	( 500,000 )
	chromic acid	( 100,000 )
	citric acid	( 500,000 )
	hydrobromic acid	( 100,000 )
	hydrochloric acid	( 350,000 )
	hydrocyanic acid	( 100,000 )
	hydrofluoric acid	( 750,000 )
	nitric acid	( 500,000 )
	picric acid	( 500,000 )
	phosphoric acid	( 500,000 )
	perchloric acid	( 500,000 )
	sulfuric acid	( 500,000 )
	potassium hydroxide	( 500,000 )
	sodium hydroxide	( 500,000 )
Products & Various Substances	antifreeze	( 500,000 )
	asphalt	( 500,000 )
	cresols	( 100,000 )
	crude oil	( 500,000 )
	diesel fuel	( 500,000 )
	fatty acids	( 500,000 )
	freon	( 500,000 )
	fuel oil	( 500,000 )
	gasoline	( 500,000 )
	hydraulic oil	( 500,000 )
	kerosene	( 500,000 )
	lacquers	( 500,000 )
	lubricating oil	( 500,000 )
	mineral spirits	( 500,000 )
Miscellaneous	naphtha	( 500,000 )
	paraffin	( 500,000 )
	transformer oil	( 500,000 )

\*potassium permanganate, potassium dichromate, chlorine, peroxides

TEMPERATURE 70 °F



## **Chemical Resistance**

*For environmental lining solutions...the world comes to GSE.®*

GSE is the world's leading supplier of high quality, polyethylene geomembranes. GSE polyethylene geomembranes are resistant to a great number and combinations of chemicals. Note that the effect of chemicals on any material is influenced by a number of variable factors such as temperature, concentration, exposed area and duration. Many tests have been performed that use geomembranes and certain specific chemical mixtures. Naturally, however, every mixture of chemicals cannot be tested for, and various criteria may be used to judge performance. Reported performance ratings may not apply to all applications of a given material in the same chemical. Therefore, these ratings are offered as a guide only.

## Abbreviations

S = Satisfactory  
L = Limited application possible

**U = Unsatisfactory**  
**— = Not tested**

Medium	Concentration	Resistance at: 20 °C (68 °F)	Resistance at: 60 °C (140 °F)
<b>A</b>			
Acetic acid	100%	S	L
Acetic acid	10%	SS	SS
Acetic acid anhydride	100%	S	L
Acetone	100%	S	L
Adipic acid	sat. sol.	SS	SS
Allyl alcohol	96%	SS	SS
Aluminum chloride	sat. sol.	SS	SS
Aluminum fluoride	sat. sol.	SS	SS
Aluminum sulfate	sat. sol.	SS	SS
Alum	sol.	SS	SS
Ammonia, aqueous	dil. sol.	SS	SS
Ammonia, gaseous dry	100%	SS	SS
Ammonia, liquid	100%	SS	SS
Ammonium chloride	sat. sol.	SS	SS
Ammonium fluoride	sol.	SS	SS
Ammonium nitrate	sat. sol.	SS	SS
Ammonium sulfate	sat. sol.	SS	SS
Ammonium sulfide	sol.	SS	SS
Amyl acetate	100%	SS	SS
Amyl alcohol	100%	SS	SS
Aniline	100%	SS	SS
Antimony trichloride	90%	SS	SS
Arsenic acid	sat. sol.	S	S
Aqua regia	HCl-HNO <sub>3</sub> 3/1	C	U
<b>B</b>			
Barium carbonate	sat. sol.	S	S
Barium chloride	sat. sol.	SS	SS
Barium hydroxide	sat. sol.	SS	SS
Barium sulfate	sat. sol.	SS	SS
Barium sulfide	sol.	SS	SS
Resinaldehyde	100%	SS	SS
Benzene	—	SS	SS
Benzoic acid	sat. sol.	SS	SS
Beer	—	SS	SS
Boron (sodium tetraborate)	sat. sol.	SS	SS
Boric acid	sat. sol.	S	S
Bromine, gaseous dry	100%	SS	SS
Bromine, liquid	100%	SS	SS
Butane, gaseous	100%	SS	SS
1-Butanol	100%	SS	SS
Butyric acid	100%	SS	SS
<b>C</b>			
Calcium carbonate	sat. sol.	SS	SS
Calcium chlorate	sat. sol.	SS	SS
Calcium chloride	sat. sol.	SS	SS
Calcium nitrate	sat. sol.	SS	SS
Calcium sulfate	sat. sol.	SS	SS
Calcium sulfide	dil. sol.	SS	SS
Carbon dioxide, gaseous dry	100%	S	S
Carbon disulfide	100%	S	S

#### **Concentration**

*sat. sol.* = Saturated aqueous solution, prepared at 20°C (68°F)

**sol.** = aqueous solution with concentration above 10% but below saturation level

dil. sol. = diluted aqueous solution with concentration below 10%

cost. conc. = customer service concentrations

Medium	Concentration	Resistance at: 20 °C (68 °F)	Resistance at: 60 °C (140 °F)
Carbon monoxide	100%	S	S
Chloroacetic acid	sol.	S	S
Carbon tetrachloride	100%	L	U
Chlorine, aqueous solution	sat. sol.	L	U
Chlorine, gaseous dry	100%	L	U
Chloroform	100%	U	U
Chromic acid	20%	S	S
Chromic acid	50%	S	S
Citric acid	sat. sol.	S	S
Copper chloride	sat. sol.	S	S
Copper nitrate	sat. sol.	S	S
Copper sulfate	sat. sol.	S	S
Cresylic acid	sat. sol.	L	S
Cyclohexanol	100%	S	S
Cyclohexanone	100%	S	S
D			
Decahydronaphthalene	100%	S	S
Dextrose	sol.	S	S
Diethyl ether	100%	S	S
Diisopropylphthalate	100%	S	S
Dioxane	100%	S	S
E			
Ethanediol	100%	S	S
Ethanol	40%	S	S
Ethyl acetate	100%	S	S
Ethylene trichloride	100%	U	U
F			
Formic chloride	sat. sol.	S	S
Formic nitrate	sol.	S	S
Formic sulfate	sat. sol.	S	S
Ferrous chloride	sat. sol.	S	S
Ferrous sulfate	sat. sol.	S	S
Fluorine, gaseous	100%	U	U
Fluorosilicic acid	40%	S	S
Formaldehyde	40%	S	S
Formic acid	50%	S	S
Formic acid	98-100%	S	S
Furfuryl alcohol	100%	S	S
G			
Gasoline	—	S	S
Glacial acetic acid	96%	S	S
Glucose	sat. sol.	S	S
Glycerine	100%	S	S
Glycol	sol.	S	S
H			
Heptane	100%	S	S
Hydrobromic acid	50%	S	S

(CONTINUED ON OTHER SIDE)

(S) Satisfactory: Liner material is resistant to the given reagent at the given concentration and temperature. No mechanical or chemical degradation is observed.

(L) **Limited Application Possible:** Liner material may reflect some attack. Factors such as concentration, pressure and temperature directly affect liner performance against the given media. Application, however, is possible under less severe conditions, e.g. lower concentration, secondary containment, additional liner protections, etc.

(U) Unsatisfactory: *Lime material is not resistant to the given reagent at the given concentration and temperature. Mechanical and/or chemical degradation is observed.*

(-) Not tested

*This information is provided for reference purposes only and is not intended as a warranty or guarantee. GSSE assumes no liability in connection with the use of this information.*

Medium	Concentration	Resistance at: 20 °C (68 °F)	Resistance at: 60 °C (140 °F)	Medium	Concentration	Resistance at: 20 °C (68 °F)	Resistance at: 60 °C (140 °F)
Hydrobromic acid	100%	S	S	Potassium permanganate	20%	S	S
Hydrochloric acid	10%	S	S	Potassium persulfate	sat. sol.	S	S
Hydrochloric acid	35%	S	S	Potassium sulfate	sat. sol.	S	S
Hydrocyanic acid	10%	S	S	Potassium sulfite	sol.	S	S
Hydrofluoric acid	4%	S	S	Propionic acid	50%	S	S
Hydrofluoric acid	60%	S	L	Propionic acid	100%	S	S
Hydrogen	100%	S	S	Pyridine	100%	S	L
Hydrogen peroxide	30%	S	L	<b>Q</b>			
Hydrogen peroxide	90%	S	U	Quinol (Hydroquinone)	sat. sol.	S	S
Hydrogen sulfide, gaseous	100%	S	S	<b>S</b>			
<b>L</b>				Salicylic acid	sat. sol.	S	S
Lactic acid	100%	S	S	Silver acetate	sat. sol.	S	S
Lead acetate	sat. sol.	S	—	Silver cyanide	sat. sol.	S	S
<b>M</b>				Silver nitrate	sat. sol.	S	S
Magnesium carbonate	sat. sol.	S	S	Sodium benzoate	sat. sol.	S	S
Magnesium chloride	sat. sol.	S	S	Sodium bicarbonate	sat. sol.	S	S
Magnesium hydroxide	sat. sol.	S	S	Sodium biphosphate	sat. sol.	S	S
Magnesium nitrate	sat. sol.	S	S	Sodium bisulfite	sol.	S	S
Maleic acid	sat. sol.	S	S	Sodium bromide	sat. sol.	S	S
Mercuric chloride	sat. sol.	S	S	Sodium carbonate	sat. sol.	S	S
Mercuric cyanide	sat. sol.	S	S	Sodium chlorate	sat. sol.	S	S
Mercuric nitrate	sol.	S	S	Sodium chloride	sat. sol.	S	S
Mercury	100%	S	S	Sodium cyanide	sat. sol.	S	S
Methanol	100%	S	S	Sodium ferricyanide	sat. sol.	S	S
Methylene chloride	100%	L	—	Sodium ferrocyanide	sat. sol.	S	S
Milk	—	S	S	Sodium fluoride	sat. sol.	S	S
Molasses	—	S	S	Sodium hydroxide	40%	S	S
<b>N</b>				Sodium hypochlorite	15% active chlorine	S	S
Nickel chloride	sat. sol.	S	S	Sodium nitrate	sat. sol.	S	S
Nickel nitrate	sat. sol.	S	S	Sodium nitrite	sat. sol.	S	S
Nickel sulfate	sat. sol.	S	S	Sodium orthophosphate	sat. sol.	S	S
Nicotinic acid	dil. sol.	S	—	Sodium sulfate	sat. sol.	S	S
Nitric acid	25%	S	S	Sodium sulfide	sat. sol.	S	S
Nitric acid	50%	S	U	Sulfur dioxide, dry	100%	S	S
Nitric acid	75%	S	U	Sulfur trioxide	100%	S	S
Nitric acid	100%	U	U	Sulfuric acid	10%	S	S
<b>O</b>				Sulfuric acid	50%	S	S
Oils and Grease	—	S	L	Sulfuric acid	98%	S	S
Oleic acid	100%	S	L	Sulfuric acid	fuming	S	S
Orthophosphoric acid	50%	S	S	Sulfurous acid	30%	S	S
Orthophosphoric acid	95%	S	L	<b>T</b>			
Oxalic acid	sat. sol.	S	S	Tannic acid	sol.	S	S
Oxygen	100%	S	L	Tartaric acid	sol.	S	S
Ozone	100%	L	U	Thionyl chloride	100%	S	S
<b>P</b>				Toluene	100%	L	S
Petroleum (kerosene)	—	S	L	Triethylamine	sol.	S	U
Phenol	sol.	S	S	<b>U</b>			
Phosphorus trichloride	100%	S	L	Urea	sol.	S	S
Photographic developer	cust. conc.	S	S	Urine	—	S	S
Picric acid	sat. sol.	S	—	<b>W</b>			
Potassium bicarbonate	sat. sol.	S	S	Water	—	S	S
Potassium bisulfide	sol.	S	S	Wine vinegar	—	S	S
Potassium bromate	sat. sol.	S	S	Wines and liquors	—	S	S
Potassium bromide	sat. sol.	S	S	<b>X</b>			
Potassium carbonate	sat. sol.	S	S	Xylenes	100%	L	U
Potassium chlorate	sat. sol.	S	S	<b>Y</b>			
Potassium chloride	sat. sol.	S	S	Yeast	sol.	S	S
Potassium chromate	sat. sol.	S	S	<b>Z</b>			
Potassium cyanide	sol.	S	S	Zinc carbonate	sat. sol.	S	S
Potassium dichromate	sat. sol.	S	S	Zinc chloride	sat. sol.	S	S
Potassium ferricyanide	sat. sol.	S	S	Zinc (II) chloride	sat. sol.	S	S
Potassium ferrocyanide	sat. sol.	S	S	Zinc (IV) chloride	sat. sol.	S	S
Potassium fluoride	sat. sol.	S	S	Zinc oxide	sat. sol.	S	S
Potassium hydroxide	10%	S	S	Zinc sulfate	sat. sol.	S	S
Potassium hydroxide	sol.	S	S				
Potassium hypochlorite	sol.	S	L				
Potassium nitrate	sat. sol.	S	S				
Potassium orthophosphate	sat. sol.	S	S				
Potassium perchlorate	sat. sol.	S	S				

Specific immersion testing should be undertaken to ascertain the suitability of chemicals not listed above with reference to special requirements.

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POLYETHYLENE

TECHNICAL SERVICE  
MEMORANDUM

TSM-243  
September, 1994

# Engineering Properties of Marlex Resins

## INTRODUCTION

It is sometimes necessary to have information about high density polyethylene (HDPE) that does not normally appear on the typical resin data sheet. This Technical Service Memorandum supplies data on many of the infrequently published physical, chemical and electrical

properties of our Marlex resins. In this Memorandum, we will briefly discuss many of these test procedures and provide available information concerning particular resin properties as well as comparing Marlex HDPE to other resin types.

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### Deformation of Plastics Under Load (ASTM D621)

*Method A: Rigid Plastics* – A 1/2 in (12.7 mm) cubical specimen is maintained under a constant compressive force of 500 pounds (227 kg) between the parallel plates of a device manufactured by the Luster Jordan Company. The whole assembly is enclosed in a constant temperature oven at 122°F (50°C). The change in thickness is observed over a period of 24 hours and reported as follows:

POLYETHYLENE MATERIAL	ORIGINAL HEIGHT, in (cm)	DEFORMED HEIGHT, in (cm)	DEFORMATION, PERCENT	TIME ELAPSED, HOURS	PRESSURE, psi (MPa)	TEMPERATURE, °F (°C)
High Density	0.506 (1.27)	0.465 (1.18)	8.1	22	2000 (13.8)	122 (50)
Low Density	0.509 (1.30)	0.425 (1.08)	16.5	24	2000 (13.8)	122 (50)

*Method B: Non-Rigid Plastics* – Method B is essentially the same as Method A except that (1) the test specimen is in the shape of a cylinder 1.129 in (28.7 mm) in diameter and 0.250 in (6.4 mm) thick having the two flat surfaces parallel; (2) the pressure is 100 psi (0.69 MPa); and (3) the test period is 3 hours. The results of testing by Method B are as follows:

POLYETHYLENE MATERIAL	ORIGINAL HEIGHT, in (cm)	DEFORMED HEIGHT, in (cm)	DEFORMATION, PERCENT	TIME ELAPSED, HOURS	PRESSURE, psi (MPa)	TEMPERATURE, °F (°C)
High Density	0.483 (1.23)	0.483 (1.23)	0	3	100 (0.69)	122 (50)
Low Density	0.498 (1.26)	0.496 (1.25)	5	3	100 (0.69)	122 (50)

### Irradiation – Effects on Properties of HDPE of Gamma and Beta Irradiation

Data indicate that polymer crosslinking occurs with beta or gamma irradiation accompanied by an increase in density, tensile strength and hardness and by a decrease in solubility. Irradiation of Marlex high density polyethylene also increases resistance to environmental stress cracking.

TYPICAL PROPERTIES	TEMPERATURE, °F (°C)	BETA IRRADIATION DOSAGE (MEGARADS)				
		0	5	10	15	50

Tensile Strength, psi (MPa)	82 (28) 200 (93) 270 (132)	4110 (28.3) 1303 (8.98) –	4217 (29.1) 1567 (10.8) 180 (1.2)	4293 (30) 1640 (11.3) 212 (1.46)	4400 (30.3) 1120 (7.7) 455 (3.13)	4560 (31.4) 1477 (10.8) 745 (5.13)
-----------------------------	----------------------------------	---------------------------------	---	--	---	--

Elongation, %	82 (28) 200 (93) 270 (132)	20 167 –	18 375 510	22 520 445	20 505 385	20 133 110
---------------	----------------------------------	----------------	------------------	------------------	------------------	------------------

Hardness, Shore D	64	67	67	68	70
Density, g/cm³	0.96	0.96	0.96	0.96	0.96

Solubility, Tetralin, 266°F (130°C)	Soluble	Insoluble	Insoluble	Insoluble	Insoluble
Color	White	White	Ivory	Ivory	Tan

TYPICAL PROPERTIES	TEMPERATURE, °F (°C)	GAMMA IRRADIATION DOSAGE (MEGARADS)			
		0	1	10	100

Tensile Strength, psi (MPa)	82 (28)	5840 (40.2)*	7007 (51.7)	7120 (49.1)	8360 (57.6)
-----------------------------	---------	--------------	-------------	-------------	-------------

Elongation, %	82 (28)	13	15	15	1
---------------	---------	----	----	----	---

Hardness, Shore D	64	68	70	70
Density, g/cm³	0.952	0.955	0.955	0.967

Solubility, Tetralin, 266°F (130°C)	Soluble	Insoluble	Insoluble	Insoluble
-------------------------------------	---------	-----------	-----------	-----------

\*Measured by different laboratories.



TABLE 9

*Effect of Gamma and Beta Irradiation of Marlex HDPE on Environmental Stress Cracking in IGEPAL CO-630 at 122°F (50°C)*

TYPE OF IRRADIATION DOSSAGE, RAD'S	$F_{50}$ VALUES, h	
	GAMMA	BETA
None	20	20
$1 \times 10^6$	20	-
$3 \times 10^6$	24	-
$6 \times 10^6$	110	40
$1 \times 10^7$	700	350
$3 \times 10^7$	350	350
$1 \times 10^8$	1	-

*Heat Deflection Temperature (ASTM D648)*

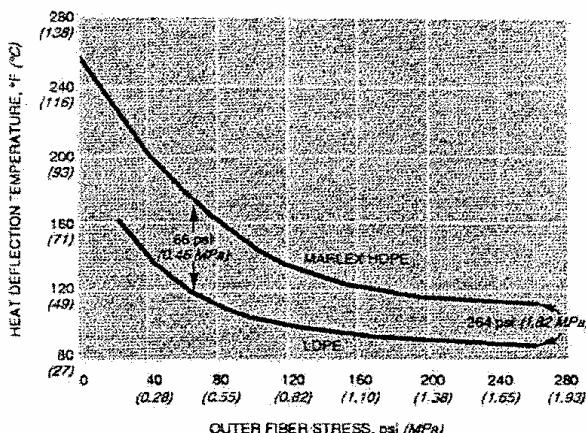
This test is primarily intended to determine the temperature at which an arbitrary deformation occurs when specimens are subjected to a specific fiber stress. It is used to indicate the behavior of plastic material at elevated temperatures in applications which are similar to the test procedure. Although this test is designed for more rigid materials such as polystyrene, unplasticized vinyl polymers and nylon, it is especially useful in comparing Marlex HDPE with other polyethylenes.

Injection molded bars 5 in. (127 mm) long, 0.5 in. (12.7 mm) wide and 0.25 in. (6.4 mm) thick are supported along the 0.25 in. edge between two points 4 in. (100 mm) apart. Weight is applied at the center of the span to impose a fiber stress of 66 psi (0.46 MPa). The bars are immersed in silicone oil and the bath temperature increased at a rate of 3.6°F (2°C) per minute. The bath temperature at the instant the specimen deflects (bends) 0.010 in. (0.254 mm) is the heat deflection temperature. In a more stringent test

which was originally designed for thermosetting resins, a heavier weight is used to impose a 264 psi (1.8 MPa) fiber stress. Therefore, care should be taken to designate the load involved when interpreting heat deflection data. Figure 6 compares the heat deflection temperature of a typical Marlex high density polyethylene with low density polyethylene at various loadings.

FIGURE 6

*Effect of Loading on Heat Deflection Temperature*

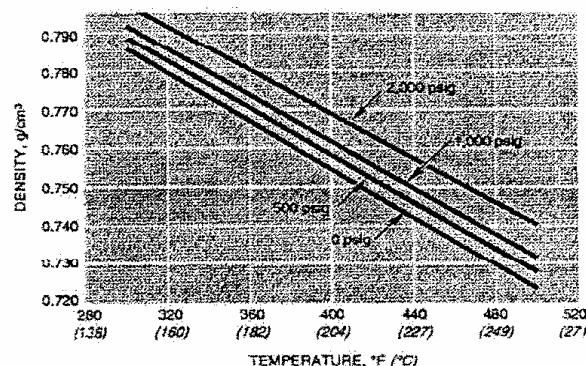


*Melt Density*

The density of molten Marlex HDPE differs from its density in the solid form. Unlike the solid density, which covers a broad range depending upon resin morphology, the density of all Marlex HDPEs in the melted state is about the same at a given temperature and pressure. The melt density may be useful in the design of extruders and other molding equipment.

FIGURE 7

*Melt Density vs. Temperature at Indicated Pressures for Marlex HDPE*



## **Appendix D**

### **Suggested Maximum Leachate Concentrations for Individual Constituents**

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## Appendix D

### Suggested Maximum Leachate Concentrations for Individual Constituents

Table D-1. Suggested maximum leachate concentrations for organic constituents for liner compatibility.

Constituent <sup>a</sup>	Predicted Concentration in Leachate <sup>b</sup> (mg/L)	Compatible Concentration for HDPE (mg/L)	Compatible Concentration for GCL (mg/L)	Compatible Concentration for Clay (mg/L)	Suggested Maximum Leachate Concentration <sup>c</sup> (mg/L)
1,1,1-Trichloroethane	0.0609	— <sup>d</sup>	— <sup>d</sup>	20 <sup>e</sup>	20
1,1,2,2-Tetrachloroethane	0.0002	—	—	—	—
1,1,2-Trichloroethane	0.0013	—	—	—	—
1,1-Dichloroethane	0.0105	—	—	—	—
1,1-Dichloroethene	0.0004	—	—	—	—
1,2,4-Trichlorobenzene	0.0113	—	—	—	—
1,2-Dichlorobenzene	0.0734	—	—	—	—
1,2-Dichloroethane	0.0001	—	—	—	—
1,2-Dichloroethene (total)	0.0003	—	—	—	—
1,3-Dichlorobenzene	0.0071	2,000 <sup>f</sup>	—	—	2,000
1,4-Dichlorobenzene	5.1303	—	—	—	—
1,4-Dioxane	0.0000	—	—	—	—
2,4,5-Trichlorophenol	0.0441	—	—	—	—
2,4,6-Trichlorophenol	0.0427	—	—	—	—
2,4-Dichlorophenol	0.0371	—	—	—	—
2,4-Dimethylphenol	0.3041	—	—	—	—
2,4-Dinitrophenol	0.1705	—	—	—	—
2,4-Dinitrotoluene	0.0488	—	—	—	—

Table D-1. (continued).

Constituent <sup>a</sup>	Predicted Concentration in Leachate <sup>b</sup> (mg/L)	Compatible Concentration for HDPE (mg/L)	Compatible Concentration for GCL (mg/L)	Compatible Concentration for Clay (mg/L)	Suggested Maximum Leachate Concentration <sup>c</sup> (mg/L)
2,6-Dinitrotoluene	0.2903	—	—	—	—
2-Butanone	0.0063	200,000 <sup>f</sup>	—	—	200,000
2-Chloronaphthalene	0.0108	2,000 <sup>g</sup>	—	—	2,000
2-Chlorophenol	0.1867	2,000 <sup>g</sup>	—	—	2,000
2-Hexanone	0.0001	—	—	—	—
2-Methylnaphthalene	1.7772	—	—	—	—
2-Methylphenol	0.2014	—	—	—	—
2-Nitroaniline	0.1728	—	—	—	—
2-Nitrophenol	0.0098	—	—	—	—
3,3'-Dichlorobenzidine	0.1896	—	—	—	—
3-Methyl Buta-1	0.0022	—	—	—	—
3-Nitroaniline	0.0165	—	—	—	—
4,6-Dinitro-2-methylphenol	0.0010	—	—	—	—
4-Bromophenyl-phenylether	0.0615	2,000 <sup>g</sup>	—	—	2,000
4-Chloro-3-methylphenol	0.0810	—	—	—	—
4-Chloroaniline	0.0052	—	—	—	—
4-Chlorophenyl-phenylether	0.0288	—	—	—	—
4-Methyl-2-Pentanone	0.1131	—	—	—	—
4-Methylphenol	0.3766	—	—	—	—
4-Nitroaniline	0.1728	—	—	—	—
4-Nitrophenol	0.0029	—	—	—	—
Acenaphthene	0.0399	2,000 <sup>g</sup>	—	—	2,000
Acenaphthylene	0.3366	2,000 <sup>g</sup>	—	—	2,000
Acetone	6.2674	200,000 <sup>g</sup>	—	—	100,000

Table D-1. (continued).

Constituent <sup>a</sup>	Predicted Concentration in Leachate <sup>b</sup> (mg/L)	Compatible Concentration for HDPE (mg/L)	Compatible Concentration for GCL (mg/L)	Compatible Concentration for Clay (mg/L)	Suggested Maximum Leachate Concentration <sup>c</sup> (mg/L)
Acetonitrile	0.0002	—	—	—	—
Acrolein	0.0001	200,000 <sup>g</sup>	—	—	200,000
Acrylonitrile	0.0000	200,000 <sup>g</sup>	—	—	200,000
Anthracene	0.0083	2,000 <sup>g</sup>	—	—	2,000
Aramite	0.0000	—	—	—	—
Aroclor-1016	0.0000	—	—	—	—
Aroclor-1254	0.0002	—	—	—	—
Aroclor-1260	0.0087	—	—	—	—
Aroclor-1268	0.2891	—	—	—	—
Benzene	1.3491	2,000 <sup>g</sup>	—	—	1,000
Benzidine	0.0000	200,000 <sup>g</sup>	—	—	200,000
Benzo(a)anthracene	0.0001	2,000 <sup>g</sup>	—	—	2,000
Benzo(a)pyrene	0.0000	2,000 <sup>g</sup>	—	—	2,000
Benzo(b)fluoranthene	0.0000	2,000 <sup>g</sup>	—	—	2,000
Benzo(g,h,i)perylene	0.0000	—	—	—	—
Benzo(k)fluoranthene	0.3024	—	—	—	—
Benzoic acid	0.1162	—	—	—	—
bis(2-Chloroethoxy)methane	0.0455	2,000 <sup>g</sup>	—	—	2,000
bis(2-Chloroethyl)ether	0.0535	2,000 <sup>g</sup>	—	—	2,000
bis(2-Chloroisopropyl)ether	0.0000	2,000 <sup>g</sup>	—	—	2,000
bis(2-Ethylhexyl)phthalate	0.5714	2,000 <sup>g</sup>	—	—	2,000
Butane,1,1,3,4-Tetrachloro-	0.0001	—	—	—	—
Butylbenzylphthalate	0.0080	200,000 <sup>g</sup>	—	—	200,000
Carbazole	0.1856	—	—	—	—

Table D-1. (continued).

Constituent <sup>a</sup>	Predicted Concentration in Leachate <sup>b</sup> (mg/L)	Compatible Concentration for HDPE (mg/L)	Compatible Concentration for GCL (mg/L)	Compatible Concentration for Clay (mg/L)	Suggested Maximum Leachate Concentration <sup>c</sup> (mg/L)
Carbon Disulfide	0.0734	—	—	—	—
Chlorobenzene	0.0679	2,000 <sup>g</sup>	—	—	2,000
Chloroethane	0.0000	—	—	—	—
Chloromethane	0.0000	2,000 <sup>g</sup>	—	—	2,000
Chrysene	4.4199	2,000 <sup>g</sup>	—	—	2,000
Decane, 3,4-Dimethyl	0.0004	—	—	—	—
Diacetone alcohol	0.0005	—	—	—	—
Dibenz(a,h)anthracene	0.0006	2,000 <sup>g</sup>	—	—	2,000
Dibenzofuran	0.4156	—	—	—	—
Diethylphthalate	0.1897	100,000 <sup>g</sup>	—	—	100,000
Dimethyl Disulfide	0.0127	—	—	—	—
Dimethylphthalate	0.0001	100,000 <sup>g</sup>	—	—	100,000
Di-n-butylphthalate	0.0000	100,000 <sup>f</sup>	—	—	100,000
Di-n-octylphthalate	0.4370	—	—	—	—
Eicosane	0.0472	—	—	—	—
Ethyl cyanide	0.0000	—	—	—	—
Ethylbenzene	0.0705	2,000 <sup>g</sup>	—	—	2,000
Famphur	0.0000	—	—	—	—
Fluoranthene	0.0221	2,000 <sup>g</sup>	—	—	2,000
Fluorene	3.0594	2,000 <sup>g</sup>	—	—	2,000
Heptadecane, 2,6,10,15-Tetra	0.0000	—	—	—	—
Hexachlorobenzene	0.0001	2,000 <sup>g</sup>	—	—	2,000
Hexachlorobutadiene	0.0000	2,000 <sup>g</sup>	—	—	2,000
Hexachlorocyclopentadiene	0.0025	2,000 <sup>g</sup>	—	—	2,000

Table D-1. (continued).

Constituent <sup>a</sup>	Predicted Concentration in Leachate <sup>b</sup> (mg/L)	Compatible Concentration for HDPE (mg/L)	Compatible Concentration for GCL (mg/L)	Compatible Concentration for Clay (mg/L)	Suggested Maximum Leachate Concentration <sup>c</sup> (mg/L)
Hexachloroethane	0.0000	2,000 <sup>g</sup>	—	—	2,000
Indeno(1,2,3-cd)pyrene	0.1585	2,000 <sup>g</sup>	—	—	2,000
Isobutyl alcohol	0.0001	500,000 <sup>g</sup>	—	—	500,000
Isophorone	0.1829	2,000 <sup>g</sup>	—	—	2,000
Isopropyl Alcohol/2-propanol	0.0000	500,000 <sup>g</sup>	—	—	500,000
Kepone	0.2511	—	—	—	—
Mesityl oxide	1.2939	—	—	—	—
Methyl Acetate	0.0057	—	—	—	—
Methylene Chloride	0.0165	2,000 <sup>g</sup>	—	20 <sup>e</sup>	20
Naphthalene	1.9193	2,000 <sup>g</sup>	—	—	2,000
Nitrobenzene	0.0948	100,000 <sup>g</sup>	—	—	100,000
N-Nitroso-di-n-propylamine	0.0035	100,000 <sup>g</sup>	—	—	100,000
N-Nitrosodiphenylamine	0.1896	100,000 <sup>g</sup>	—	—	100,000
Octane,2,3,7-Trimethyl	0.0027	—	—	—	—
o-Toluenesulfonamide	0.0033	—	—	—	—
Pentachlorophenol	0.0046	100,000 <sup>g</sup>	—	—	100,000
Phenanthrene	8.8500	2,000 <sup>g</sup>	—	—	2,000
Phenol	0.1370	100,000 <sup>g</sup>	—	—	100,000
Phenol,2,6-Bis(1,1-Dimethyl)	0.0674	—	—	—	—
p-Toluenesulfonamide	0.0000	—	—	—	—
Pyrene	3.2501	2,000 <sup>g</sup>	—	—	2,000
RDX	0.0000	5,000 <sup>g</sup>	—	—	5,000
Styrene	0.0000	2,000 <sup>g</sup>	—	—	2,000
Tetrachloroethene	0.0235	5,000 <sup>g</sup>	—	20 <sup>h</sup>	20

Table D-1. (continued).

Constituent <sup>a</sup>	Predicted Concentration in Leachate <sup>b</sup> (mg/L)	Compatible Concentration for HDPE (mg/L)	Compatible Concentration for GCL (mg/L)	Compatible Concentration for Clay (mg/L)	Suggested Maximum Leachate Concentration <sup>c</sup> (mg/L)
Toluene	16.3666	—	—	—	—
Tributylphosphate	1.2292	2,000 <sup>g</sup>	—	1,100 <sup>e</sup>	1,100
Trichloroethene	1.1526	—	—	—	—
Trinitrotoluene	0.0000	—	—	—	—
Undecane,4,6-Dimethyl-	0.0003	5,000 <sup>g</sup>	—	—	5,000
Xylene (ortho)	0.0071	—	—	—	—
Xylene (total)	6.2805	—	—	—	—

Notes

a. Constituent reported in the "INEEL CERCLA Disposal Facility Design Inventory (EDF-ER-264).

b. Predicted leachate concentration in the first year of the ICDF landfill operation (EDF-ER-274).

c. The suggested maximum concentration selected for the ICDF liner system is based on the lowest of the concentrations listed for HDPE, GCL, and clay materials and are applicable for the leachate in the landfill and the waste liquids in the evaporation ponds.

d. “—” indicates that a specific test value was not available, compatibility issues are not anticipated.

e. The TCE solubility limit in water is 1,100 mg/l. A minimum of 2 pore volumes of permeant liquid was passed through the clay sample or until the concentration of total organic carbon in the influent and effluent were the same (Bowders and Daniel 1988). No significant change in permeability was observed.

f. From "Evaluation of Liner/Leachate Chemical Compatibility for the Environmental Restoration Disposal Facility," BHI-00359.

g. From manufacturer specifications.

h. 20 mg/l is the typical concentration of leachate found in municipal landfills. No change in clay permeability was observed at this concentration (Kim, Tuncer, and Park 1999).

Table D-2. Suggested maximum leachate concentrations for inorganic constituent for liner compatibility.

Constituent <sup>a</sup>	Predicted Concentration in Leachate <sup>b</sup> (mg/L)	Compatible Concentration for HDPE (mg/l)	Compatible Concentration for GCL (mg/l)	Compatible Concentration for Clay (mg/l)	Suggested Maximum Leachate Concentration <sup>c</sup> (mg/l)
Aluminum	28.3029				
Antimony	0.1165				
Arsenic	1.8470	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Barium	3.5848				
Beryllium	0.0011				
Boron	36.4728	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Cadmium	0.5917	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Calcium	4035.0217	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Chloride	31.1061				
Chromium	1.3691				
Cobalt	0.5999	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Copper	1.4906	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Cyanide	4.0932	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Dysprosium	0.2472				
Fluoride	64.4341				
Iron	46.5528				
Lead	0.5753				
Magnesium	883.9838	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Manganese	4.1300				
Mercury	49.6286				
Molybdenum	1.0117	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Nickel	0.1964				
Nitrate	65.4429				
Nitrate/Nitrite-N	3.6979				
Nitrite	0.1414				
Phosphorus	19.2492	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Potassium	74.8819	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Selenium	0.2084	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Silver	0.1092				
Sodium	2.7716				
Strontium	1.5094	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Sulfate	342.1180				

Table D-2. (continued).

Constituent <sup>a</sup>	Predicted Concentration in Leachate <sup>b</sup> (mg/L)	Compatible Concentration for HDPE (mg/l)	Compatible Concentration for GCL (mg/l)	Compatible Concentration for Clay (mg/l)	Suggested Maximum Leachate Concentration <sup>c</sup> (mg/l)
Sulfide	12641.8391				
Terbium	2.3867				
Thallium	0.0037				
Vanadium	3.5063	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Ytterbium	0.8124				
Zinc	12.9486	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Zirconium	0.1151				
Total Inorganic	18367.1936				

a. Constituent reported in the 'INEEL CERCLA Disposal Facility Design Inventory (EDF-ER-264).

b. Predicted leachate concentration in the first year of the ICDF landfill operation (EDF-ER-274).

c. The suggested maximum concentration selected for the ICDF liner system is based on the lowest of the concentrations listed for HDPE, GCL, and clay materials and are applicable for the leachate in the landfill and the waste liquids in the evaporation ponds.

d. From manufacturer specifications

e. From manufacturer specifications

Table D-3. Suggested maximum leachate concentrations for radionuclide constituents for liner compatibility in the ICDF Landfill.

Constituent <sup>a</sup>	Predicted Activity Concentration in Leachate <sup>b</sup> (pCi/L)	Suggested Maximum Activity Concentration <sup>c</sup> (pCi/L)
Ac225	1.1E-07	2.2E+07
Ac227	4.5E-05	1.6E+09
Ac228	3.4E-10	9.4E+07
Ag106	0.0E+00	2.0E+08
Ag108	4.1E-08	—
Ag108m	8.9E+00	7.8E+07
Ag109m	5.5E-11	1.5E+09
Ag110	5.7E-10	1.1E+08
Ag110m	6.2E-08	4.6E+07
Ag111	0.0E+00	—
Am241	7.0E+01	2.3E+07
Am242	1.3E-04	6.7E+08
Am242m	1.3E-04	1.9E+09
Am243	9.8E-04	2.4E+07
Am245	0.0E+00	—
Am246	4.1E-25	1.0E+08
At217	8.5E-04	1.8E+07
Ba136m	0.0E+00	—
Ba137m	4.6E+05	1.9E+08
Ba140	0.0E+00	—
Be10	4.6E-06	6.3E+08
Bi210	1.1E-05	3.3E+08
Bi211	1.8E-04	1.9E+07
Bi212	5.5E-03	4.5E+07
Bi213	0.0E+00	—
Bi214	5.6E-05	5.9E+07
Bk249	5.4E-22	3.9E+09
Bk250	1.9E-26	1.1E+08
C14	9.1E-03	2.6E+09
Cd109	8.1E-10	6.5E+09
Cd113m	2.7E+02	6.9E+08
Cd115m	7.0E-52	2.0E+08
Ce141	3.6E-71	5.2E+08
Ce142	0.0E+00	—
Ce144	3.6E-03	1.1E+09
Cf249	8.1E-16	2.1E+07

Table D-3. (continued).

Constituent <sup>a</sup>	Predicted Activity Concentration in Leachate <sup>b</sup> (pCi/L)	Suggested Maximum Activity Concentration <sup>c</sup> (pCi/L)
Cf250	4.1E-16	2.1E+07
Cf251	1.9E-18	2.2E+07
Cf252	4.4E-20	1.2E+10
Cm241	3.2E-81	7.5E+08
Cm242	1.3E-17	2.1E+07
Cm243	8.9E-07	2.1E+07
Cm244	4.5E-04	2.2E+07
Cm245	2.0E-08	2.3E+07
Cm246	4.5E-10	2.4E+07
Cm247	1.6E-16	2.4E+07
Cm248	4.9E-17	2.7E+07
Cm250	1.4E-25	9.8E+07
Co57	3.7E-01	8.9E+08
Co58	5.8E-15	1.3E+08
Co60	1.9E+04	4.9E+07
Cr51	7.7E-53	3.5E+09
Cs132	0.0E+00	—
Cs134	2.2E+01	7.4E+07
Cs135	7.2E-02	2.3E+09
Cs136	0.0E+00	—
Cs137	4.9E+04	7.5E+08
Er169	0.0E+00	—
Eu150	5.1E-08	4.4E+08
Eu152	2.8E+03	1.0E+08
Eu154	2.4E+03	8.4E+07
Eu155	5.2E+02	1.0E+09
Eu156	0.0E+00	—
Fe59	2.0E-34	9.8E+07
Fr221	1.0E-07	2.0E+07
Fr223	5.6E-07	2.9E+08
Gd152	1.1E-13	5.9E+07
Gd153	8.4E-11	8.4E+08
H3	8.3E+05	2.2E+10
Hf181	1.7E-36	1.7E+08
Ho166m	1.1E-05	7.3E+07
I129	2.2E+04	1.6E+09
I131	0.0E+00	—

Table D-3. (continued).

Constituent <sup>a</sup>	Predicted Activity Concentration in Leachate <sup>b</sup> (pCi/L)	Suggested Maximum Activity Concentration <sup>c</sup> (pCi/L)
In114	4.8E-54	1.6E+08
In114m	5.1E-54	5.3E+08
In115	1.5E-11	8.4E+08
In115m	0.0E+00	—
K40	1.3E+02	2.1E+08
Kr81 <sup>d</sup>	8.8E-05	—
Kr85 <sup>d</sup>	1.9E+07	—
La138	0.0E+00	—
La140	2.2E-105	4.5E+07
Mn54	3.9E-07	1.5E+08
Nb92	6.3E-18	8.5E+07
Nb93m	1.3E-01	4.2E+09
Nb94	8.8E-05	7.4E+07
Nb95	4.8E-32	1.6E+08
Nb95m	1.8E-34	5.2E+08
Nd144	1.4E-09	6.7E+07
Nd147	0.0E+00	—
Np235	8.4E-09	1.3E+10
Np236	8.6E-06	3.7E+08
Np237	8.0E+01	2.6E+07
Np238	2.7E-05	1.6E+08
Np239	4.1E-02	3.1E+08
Np240	3.5E-12	8.0E+07
Np240m	3.1E-09	1.3E+08
Pa231	1.3E-04	2.3E+07
Pa233	7.9E-02	3.1E+08
Pa234	5.0E-06	5.2E+07
Pa234m	3.1E-03	1.5E+08
Pb209	4.8E-07	6.5E+08
Pb210	1.1E-05	3.3E+09
Pb211	1.8E-04	2.5E+08
Pb212	5.5E-03	4.0E+08
Pb214	5.6E-05	2.4E+08
Pd107	1.1E-01	3.9E+09
Pm146	2.4E-02	1.5E+08
Pm147	1.6E+03	2.1E+09
Pm148	1.7E-58	9.8E+07

Table D-3. (continued).

Constituent <sup>a</sup>	Predicted Activity Concentration in Leachate <sup>b</sup> (pCi/L)	Suggested Maximum Activity Concentration <sup>c</sup> (pCi/L)
Pm148m	3.4E-57	5.9E+07
Po210	6.8E-06	2.4E+07
Po211	4.6E-09	1.7E+07
Po212	2.2E-03	1.5E+07
Po213	2.9E-07	1.5E+07
Po214	3.7E-05	1.7E+07
Po215	1.2E-04	1.7E+07
Po216	3.7E-03	1.9E+07
Po218	3.7E-05	2.1E+07
Pr143	0.0E+00	—
Pr144	7.4E-03	1.0E+08
Pr144m	1.1E-04	1.1E+10
Pu236	3.9E-05	2.2E+07
Pu237	8.6E-58	2.1E+09
Pu238	1.7E+03	2.3E+07
Pu239	4.8E+01	2.5E+07
Pu240	1.1E+01	2.5E+07
Pu241	4.6E+02	2.4E+10
Pu242	1.7E-03	2.6E+07
Pu243	4.6E-15	6.6E+08
Pu244	1.8E-10	2.8E+07
Pu246	9.9E-25	8.3E+08
Ra222	1.2E-115	2.0E+07
Ra223	2.0E-04	2.2E+07
Ra224	5.5E-03	2.2E+07
Ra225	5.1E-07	1.1E+09
Ra226	4.7E+00	2.7E+07
Ra228	1.5E-09	1.1E+10
Rb86	0.0E+00	—
Rb87	2.0E-04	1.6E+09
Rh102	5.7E-04	1.6E+09
Rh103m	5.4E-57	3.3E+09
Rh106	2.2E-01	7.9E+07
Rn218	2.1E-112	1.8E+07
Rn219	3.4E-01	1.9E+07
Rn220	9.2E+00	2.0E+07
Rn222	1.0E-01	2.3E+07

Table D-3. (continued).

Constituent <sup>a</sup>	Predicted Activity Concentration in Leachate <sup>b</sup> (pCi/L)	Suggested Maximum Activity Concentration <sup>c</sup> (pCi/L)
Ru103	3.6E-28	2.3E+08
Ru106	2.2E-01	3.2E+09
Sb124	4.1E-39	5.7E+07
Sb125	1.9E+02	2.4E+08
Sb126	4.1E-01	4.2E+07
Sb126m	2.9E+00	5.9E+07
Sc46	9.2E-20	6.0E+07
Se79	4.1E+01	2.4E+09
Sm146	1.8E-09	5.1E+07
Sm147	1.7E-05	5.7E+07
Sm148	4.2E-12	6.4E+07
Sm149 <sup>e</sup>	2.1E-11	—
Sm151	1.4E+03	6.5E+09
Sn117m	0.0E+00	—
Sn119m	1.1E-06	6.5E+09
Sn121m	2.1E-01	1.5E+09
Sn123	6.5E-16	4.2E+10
Sn125	0.0E+00	—
Sn126	1.1E+00	2.4E+08
Sr89	5.0E-42	3.6E+08
Sr90	1.9E+06	2.2E+08
Tb160	1.3E-33	2.3E+08
Tb161	0.0E+00	—
Tc98	6.8E-04	9.5E+07
Tc99	2.2E+04	8.4E+07
Te123	3.6E-14	1.5E+09
Te123m	2.4E-22	7.5E+09
Te125m	1.8E+01	5.2E+08
Te127	7.5E-19	8.0E+08
Te127m	7.6E-19	5.6E+08
Te129	5.4E-70	1.4E+09
Te129m	8.6E-70	2.1E+08
Th226	2.2E-116	4.1E+08
Th227	1.8E-04	2.0E+07
Th228	3.3E-01	2.1E+07
Th229	5.1E-07	2.4E+07
Th230	1.7E+00	2.5E+07

Table D-3. (continued).

Constituent <sup>a</sup>	Predicted Activity Concentration in Leachate <sup>b</sup> (pCi/L)	Suggested Maximum Activity Concentration <sup>c</sup> (pCi/L)
Th231	1.6E+00	2.7E+07
Th232	1.6E+00	7.2E+08
Th234	1.7E-02	3.2E+07
Tl207	1.8E-04	1.9E+09
Tl208	2.0E-03	2.6E+08
Tl209	1.1E-08	3.2E+07
Tm170	2.7E-25	3.2E+07
Tm171	6.6E-12	3.8E+08
U230	0.0E+00	—
U232	8.8E-02	4.9E+09
U233	4.2E-03	2.4E+07
U234	9.9E+02	2.7E+07
U235	1.8E+01	2.7E+07
U236	3.3E+01	2.8E+07
U237	0.0E+00	—
U238	3.2E+02	2.8E+07
U240	4.2E-09	3.0E+07
Xe127	2.6E-68	8.0E+08
Xe129m	0.0E+00	—
Xe131m	4.5E-108	4.1E+08
Xe133	0.0E+00	—
Y90	1.3E+05	7.9E+08
Y91	2.4E-36	1.3E+08
Zn65	1.7E-07	2.1E+08
Zr93	1.4E+00	2.2E+08
Zr95	4.9E-25	6.6E+09

Notes:

Constituent reported in the "INEEL CERCLA Disposal Facility Design Inventory" (EDF-ER-264).

Predicted average leachate activity concentration during the 15 year operational period.

The suggested maximum activity concentration selected for the ICDF liner system is based on a total absorbed dose of 1,000,000 rads for the individual constituent and a 4 cm leachate depth.

The constituents are gaseous elements so not part of the leachate.

No energy emitted since stable isotope.

Table D-4. Suggested maximum leachate concentrations for radionuclide constituents for liner compatibility in the ICDF Evaporation Pond.

Constituent <sup>a</sup>	Predicted Activity Concentration in Leachate <sup>b</sup> (pCi/L)	Suggested Maximum Activity Concentration <sup>c</sup> (pCi/L)
Ac225	1.1E-07	2.4E+06
Ac227	4.5E-05	1.8E+08
Ac228	3.4E-10	1.0E+07
Ag106	0.0E+00	2.3E+07
Ag108	4.1E-08	—
Ag108m	8.9E+00	8.7E+06
Ag109m	5.5E-11	1.6E+08
Ag110	5.7E-10	1.2E+07
Ag110m	6.2E-08	5.1E+06
Ag111	0.0E+00	—
Am241	7.0E+01	2.6E+06
Am242	1.3E-04	7.4E+07
Am242m	1.3E-04	2.2E+08
Am243	9.8E-04	2.7E+06
Am245	0.0E+00	—
Am246	4.1E-25	1.1E+07
At217	8.5E-04	2.0E+06
Ba136m	0.0E+00	—
Ba137m	4.6E+05	2.1E+07
Ba140	0.0E+00	—
Be 10	4.6E-06	7.0E+07
Bi210	1.1E-05	3.7E+07
Bi211	1.8E-04	2.2E+06
Bi212	5.5E-03	5.0E+06
Bi213	0.0E+00	—
Bi214	5.6E-05	6.6E+06
Bk249	5.4E-22	4.3E+08
Bk250	1.9E-26	1.2E+07
C14	9.1E-03	2.9E+08
Cd109	8.1E-10	7.2E+08
Cd113m	2.7E+02	7.7E+07
Cd115m	7.0E-52	2.3E+07
Ce141	3.6E-71	5.8E+07
Ce142	0.0E+00	—
Ce144	3.6E-03	1.3E+08
Cf249	8.1E-16	2.3E+06

Table D-4. (continued).

Constituent <sup>a</sup>	Predicted Activity Concentration in Leachate <sup>b</sup> (pCi/L)	Suggested Maximum Activity Concentration <sup>c</sup> (pCi/L)
Cf250	4.1E-16	2.4E+06
Cf251	1.9E-18	2.4E+06
Cf252	4.4E-20	1.4E+09
Cm241	3.2E-81	8.3E+07
Cm242	1.3E-17	2.3E+06
Cm243	8.9E-07	2.3E+06
Cm244	4.5E-04	2.4E+06
Cm245	2.0E-08	2.6E+06
Cm246	4.5E-10	2.6E+06
Cm247	1.6E-16	2.7E+06
Cm248	4.9E-17	3.1E+06
Cm250	1.4E-25	1.1E+07
Co57	3.7E-01	9.9E+07
Co58	5.8E-15	1.5E+07
Co60	1.9E+04	5.5E+06
Cr51	7.7E-53	3.9E+08
Cs132	0.0E+00	—
Cs134	2.2E+01	8.3E+06
Cs135	7.2E-02	2.5E+08
Cs136	0.0E+00	—
Cs137	4.9E+04	8.3E+07
Er169	0.0E+00	—
Eu150	5.1E-08	4.9E+07
Eu152	2.8E+03	1.1E+07
Eu154	2.4E+03	9.3E+06
Eu155	5.2E+02	1.2E+08
Eu156	0.0E+00	—
Fe59	2.0E-34	1.1E+07
Fr221	1.0E-07	2.2E+06
Fr223	5.6E-07	3.3E+07
Gd152	1.1E-13	6.6E+06
Gd153	8.4E-11	9.3E+07
H3	8.3E+05	2.5E+09
Hf181	1.7E-36	1.9E+07
Ho166m	1.1E-05	8.2E+06
I129	2.2E+04	1.8E+08
I131	0.0E+00	-

Table D-4. (continued).

Constituent <sup>a</sup>	Predicted Activity Concentration in Leachate <sup>b</sup> (pCi/L)	Suggested Maximum Activity Concentration <sup>c</sup> (pCi/L)
In114	4.8E-54	1.8E+07
In114m	5.1E-54	5.9E+07
In115	1.5E-11	9.3E+07
In115m	0.0E+00	—
K40	1.3E+02	2.3E+07
Kr81 <sup>d</sup>	8.8E-05	—
Kr85 <sup>d</sup>	1.9E+07	—
La138	0.0E+00	—
La140	2.2E-105	5.0E+06
M54	3.9E-07	1.7E+07
Nb92	6.3E-18	9.4E+06
Nb93m	1.3E-01	4.7E+08
Nb94	8.8E-05	8.3E+06
Nb95	4.8E-32	1.8E+07
Nb95m	1.8E-34	5.8E+07
Nd144	1.4E-09	7.5E+06
Nd147	0.0E+00	—
Np235	8.4E-09	1.4E+09
Np236	8.6E-06	4.2E+07
Np237	8.0E+01	2.9E+06
Np238	2.7E-05	1.8E+07
Np239	4.1E-02	3.4E+07
Np240	3.5E-12	8.9E+06
Np240m	3.1E-09	1.5E+07
Pa231	1.3E-04	2.6E+06
Pa233	7.9E-02	3.5E+07
Pa234	5.0E-06	5.8E+06
Pa234m	3.1E-03	1.7E+07
Pb209	4.8E-07	7.2E+07
Pb210	1.1E-05	3.7E+08
Pb211	1.8E-04	2.8E+07
Pb212	5.5E-03	4.4E+07
Pb214	5.6E-05	2.6E+07
Pd107	1.1E-01	4.3E+08
Pm146	2.4E-02	1.7E+07
Pm147	1.6E+03	2.3E+08
Pm148	1.7E-58	1.1E+07

Table D-4. (continued).

Constituent <sup>a</sup>	Predicted Activity Concentration in Leachate <sup>b</sup> (pCi/L)	Suggested Maximum Activity Concentration <sup>c</sup> (pCi/L)
Pm148m	3.4E-57	6.6E+06
Po210	6.8E-06	2.7E+06
Po211	4.6E-09	1.9E+06
Po212	2.2E-03	1.6E+06
Po213	2.9E-07	1.7E+06
Po214	3.7E-05	1.8E+06
Po215	1.2E-04	1.9E+06
Po216	3.7E-03	2.1E+06
Po218	3.7E-05	2.4E+06
Pr143	0.0E+00	—
Pr144	7.4E-03	1.1E+07
Pr144m	1.1E-04	1.2E+09
Pu236	3.9E-05	2.5E+06
Pu237	8.6E-58	2.3E+08
Pu238	1.7E+03	2.6E+06
Pu239	4.8E+01	2.8E+06
Pu240	1.1E+01	2.8E+06
Pu241	4.6E+02	2.7E+09
Pu242	1.7E-03	2.9E+06
Pu243	4.6E-15	7.3E+07
Pu244	1.8E-10	3.1E+06
Pu246	9.9E-25	9.2E+07
Ra222	1.2E-115	2.2E+06
Ra223	2.0E-04	2.4E+06
Ra224	5.5E-03	2.5E+06
Ra225	5.1E-07	1.2E+08
Ra226	4.7E+00	3.0E+06
Ra228	1.5E-09	1.2E+09
Rb86	0.0E+00	—
Rb87	2.0E-04	1.8E+08
Rh102	5.7E-04	1.8E+08
Rh103m	5.4E-57	3.7E+08
Rh106	2.2E-01	8.8E+06
Rn218	2.1E-112	2.0E+06
Rn219	3.4E-01	2.1E+06
Rn220	9.2E+00	2.3E+06
Rn222	1.0E-01	2.6E+06

Table D-4. (continued).

Constituent <sup>a</sup>	Predicted Activity Concentration in Leachate <sup>b</sup> (pCi/L)	Suggested Maximum Activity Concentration <sup>c</sup> (pCi/L)
Ru103	3.6E-28	2.6E+07
Ru106	2.2E-01	3.6E+08
Sb124	4.1E-39	6.3E+06
Sb125	1.9E+02	2.7E+07
Sb126	4.1E-01	4.7E+06
Sb126m	2.9E+00	6.6E+06
Sc46	9.2E-20	6.7E+06
Se79	4.1E+01	2.7E+08
Sm146	1.8E-09	5.6E+06
Sm147	1.7E-05	6.3E+06
Sm148	4.2E-12	7.1E+06
Sm149 <sup>e</sup>	2.1E-11	—
Sm151	1.4E+03	7.2E+08
Sn117m	0.0E+00	—
Sn119m	1.1E-06	7.2E+08
Sn121m	2.1E-01	1.6E+08
Sn123	6.5E-16	4.7E+09
Sn125	0.0E+00	—
Sn126	1.1E+00	2.7E+07
Sr89	5.0E-42	4.0E+07
Sr90	1.9E+06	2.4E+07
Tb160	1.3E-33	2.6E+07
Tb161	0.0E+00	—
Tc98	6.8E-04	1.1E+07
Tc99	2.2E+04	9.4E+06
Te123	3.6E-14	1.7E+08
Te123m	2.4E-22	8.3E+08
Te125m	1.8E+01	5.8E+07
Te127	7.5E-19	8.9E+07
Te127m	7.6E-19	6.2E+07
Te129	5.4E-70	1.6E+08
Te129m	8.6E-70	2.4E+07
Th226	2.2E-116	4.6E+07
Th227	1.8E-04	2.2E+06
Th228	3.3E-01	2.3E+06
Th229	5.1E-07	2.6E+06
Th230	1.7E+00	2.8E+06

Table D-4. (continued).

Constituent <sup>a</sup>	Predicted Activity Concentration in Leachate <sup>b</sup> (pCi/L)	Suggested Maximum Activity Concentration <sup>c</sup> (pCi/L)
Th231	1.6E+00	3.0E+06
Th232	1.6E+00	8.0E+07
Th234	1.7E-02	3.5E+06
Tl207	1.8E-04	2.1E+08
Tl208	2.0E-03	2.9E+07
Tl209	1.1E-08	3.6E+06
Tm170	2.7E-25	3.6E+06
Tm171	6.6E-12	4.2E+07
U230	0.0E+00	—
U232	8.8E-02	5.4E+08
U233	4.2E-03	2.7E+06
U234	9.9E+02	2.9E+06
U235	1.8E+01	3.0E+06
U236	3.3E+01	3.1E+06
U237	0.0E+00	—
U238	3.2E+02	3.2E+06
U240	4.2E-09	3.4E+06
Xe127	2.6E-68	8.9E+07
Xe129m	0.0E+00	—
Xe131m	4.5E-108	4.6E+07
Xe133	0.0E+00	—
Y90	1.3E+05	8.8E+07
Y91	2.4E-36	1.5E+07
Zn65	1.7E-07	2.3E+07
Zr93	1.4E+00	2.4E+07
Zr95	4.9E-25	7.3E+08

Notes:

- a. Constituent reported in the "INEEL CERCLA Disposal Facility Design Inventory (EDF-ER-264).
- b. Predicted average leachate activity concentration during the 15 year operational period.
- c. The suggested maximum activity concentration selected for the ICDF liner system is based on a total absorbed dose of 1,000,000 rads for the individual constituent and a 36 cm liquid waste depth.
- d. The constituents are gaseous elements so not part of the leachate.
- e. Stable isotope

## **Appendix E**

### **Suggested Maximum Leachate Concentrations for Individual Constituents in Evaporation Pond Liquid**

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## Appendix E

### Suggested Maximum Leachate Concentrations for Individual Constituents in Evaporation Pond Liquid

Table E-1. Suggested maximum leachate concentrations for organic constituents for liner compatibility in evaporation pond.

Constituent <sup>a</sup>	Predicted Concentration in Leachate <sup>b</sup> (mg/L)	Compatible Concentration for HDPE (mg/L)	Compatible Concentration for GCL (mg/L)	Compatible Concentration for Clay (mg/L)	Suggested Maximum Leachate Concentration <sup>c</sup> (mg/L)
1,1,1-Trichloroethane	0.0609	- <sup>d</sup>	- <sup>d</sup>	20 <sup>e</sup>	20
1,1,2,2-Tetrachloroethane	0.0002	—	—	—	—
1,1,2-Trichloroethane	0.0013	—	—	—	—
1,1-Dichloroethane	0.0105	—	—	—	—
1,1-Dichloroethene	0.0004	—	—	—	—
1,2,4-Trichlorobenzene	0.0113	—	—	—	—
1,2-Dichlorobenzene	0.0734	—	—	—	—
1,2-Dichloroethane	0.0001	—	—	—	—
1,2-Dichloroethene (total)	0.0003	—	—	—	—
1,3-Dichlorobenzene	0.0071	2,000 <sup>f</sup>	—	—	2,000
1,4-Dichlorobenzene	5.1303	—	—	—	—
1,4-Dioxane	0.0000	—	—	—	—
2,4,5-Trichlorophenol	0.0441	—	—	—	—
2,4,6-Trichlorophenol	0.0427	—	—	—	—
2,4-Dichlorophenol	0.0371	—	—	—	—
2,4-Dimethylphenol	0.3041	—	—	—	—
2,4-Dinitrophenol	0.1705	—	—	—	—
2,4-Dinitrotoluene	0.0488	—	—	—	—
2,6-Dinitrotoluene	0.2903	—	—	—	—
2-Butanone	0.0063	200,000 <sup>f</sup>	—	—	200,000
2-Chloronaphthalene	0.0108	2,000 <sup>g</sup>	—	—	2,000
2-Chlorophenol	0.1867	2,000 <sup>g</sup>	—	—	2,000
2-Hexanone	0.0001	—	—	—	—
2-Methylnaphthalene	1.7772	—	—	—	—
2-Methylphenol	0.2014	—	—	—	—
2-Nitroaniline	0.1728	—	—	—	—
2-Nitrophenol	0.0098	—	—	—	—
3,3'-Dichlorobenzidine	0.1896	—	—	—	—
3-Methyl Buta-1	0.0022	—	—	—	—
3-Nitroaniline	0.0165	—	—	—	—
4,6-Dinitro-2-methylphenol	0.0010	—	—	—	—

Table E-1. (continued).

Constituent <sup>a</sup>	Predicted Concentration in Leachate <sup>b</sup> (mg/L)	Compatible Concentration for HDPE (mg/L)	Compatible Concentration for GCL (mg/L)	Compatible Concentration for Clay (mg/L)	Suggested Maximum Leachate Concentration <sup>c</sup> (mg/L)
4-Bromophenyl-phenylether	0.0615	2,000 <sup>g</sup>	—	—	2,000
4-Chloro-3-methylphenol	0.0810	—	—	—	—
4-Chloroaniline	0.0052	—	—	—	—
4-Chlorophenyl-phenylether	0.0288	—	—	—	—
4-Methyl-2-Pentanone	0.1131	—	—	—	—
4-Methylphenol	0.3766	—	—	—	—
4-Nitroaniline	0.1728	—	—	—	—
4-Nitrophenol	0.0029	—	—	—	—
Acenaphthene	0.0399	2,000 <sup>g</sup>	—	—	2,000
Acenaphthylene	0.3366	2,000 <sup>g</sup>	—	—	2,000
Acetone	6.2674	200,000 <sup>g</sup>	—	—	100,000
Acetonitrile	0.0002	-	—	—	-
Acrolein	0.0001	200,000 <sup>g</sup>	—	—	200,000
Acrylonitrile	0.0000	200,000 <sup>g</sup>	—	—	200,000
Anthracene	0.0083	2,000 <sup>g</sup>	—	—	2,000
Aramite	0.0000	—	—	—	—
Aroclor-1016	0.0000	—	—	—	—
Aroclor-1254	0.0002	—	—	—	—
Aroclor-1260	0.0087	—	—	—	—
Aroclor-1268	0.2891	—	—	—	—
Benzene	1.3491	2,000 <sup>g</sup>	—	—	1,000
Benzidine	0.0000	200,000 <sup>g</sup>	—	—	200,000
Benzo(a)anthracene	0.0001	2,000 <sup>g</sup>	—	—	2,000
Benzo(a)pyrene	0.0000	2,000 <sup>g</sup>	—	—	2,000
Benzo(b)fluoranthene	0.0000	2,000 <sup>g</sup>	—	—	2,000
Benzo(g,h,i)perylene	0.0000	—	—	—	—
Benzo(k)fluoranthene	0.3024	—	—	—	—
Benzoic acid	0.1162	—	—	—	—
bis(2-Chloroethoxy)methane	0.0455	2,000 <sup>g</sup>	—	—	2,000
bis(2-Chloroethyl)ether	0.0535	2,000 <sup>g</sup>	—	—	2,000
bis(2-Chloroisopropyl)ether	0.0000	2,000 <sup>g</sup>	—	—	2,000
bis(2-Ethylhexyl)phthalate	0.5714	2,000 <sup>g</sup>	—	—	2,000
Butane,1,1,3,4-Tetrachloro-	0.0001	—	—	—	—
Butylbenzylphthalate	0.0080	200,000 <sup>g</sup>	—	—	200,000
Carbazole	0.1856	—	—	—	—
Carbon Disulfide	0.0734	—	—	—	—

Table E-1. (continued).

Constituent <sup>a</sup>	Predicted Concentration in Leachate <sup>b</sup> (mg/L)	Compatible Concentration for HDPE (mg/L)	Compatible Concentration for GCL (mg/L)	Compatible Concentration for Clay (mg/L)	Suggested Maximum Leachate Concentration <sup>c</sup> (mg/L)
Chlorobenzene	0.0679	2,000 <sup>g</sup>	—	—	2,000
Chloroethane	0.0000	—	—	—	—
Chloromethane	0.0000	2,000 <sup>g</sup>	—	—	2,000
Chrysene	4.4199	2,000 <sup>g</sup>	—	—	2,000
Decane, 3,4-Dimethyl	0.0004	—	—	—	—
Diacetone alcohol	0.0005	—	—	—	—
Dibenz(a,h)anthracene	0.0006	2,000 <sup>g</sup>	—	—	2,000
Dibenzofuran	0.4156	—	—	—	—
Diethylphthalate	0.1897	100,000 <sup>g</sup>	—	—	100,000
Dimethyl Disulfide	0.0127	—	—	—	—
Dimethylphthalate	0.0001	100,000 <sup>g</sup>	—	—	100,000
Di-n-butylphthalate	0.0000	100,000 <sup>f</sup>	—	—	100,000
Di-n-octylphthalate	0.4370	—	—	—	—
Eicosane	0.0472	—	—	—	—
Ethyl cyanide	0.0000	—	—	—	—
Ethylbenzene	0.0705	2,000 <sup>g</sup>	—	—	2,000
Famphur	0.0000	—	—	—	—
Fluoranthene	0.0221	2,000 <sup>g</sup>	—	—	2,000
Fluorene	3.0594	2,000 <sup>g</sup>	—	—	2,000
Heptadecane, 2,6,10,15-Tetra	0.0000	—	—	—	—
Hexachlorobenzene	0.0001	2,000 <sup>g</sup>	—	—	2,000
Hexachlorobutadiene	0.0000	2,000 <sup>g</sup>	—	—	2,000
Hexachlorocyclopentadiene	0.0025	2,000 <sup>g</sup>	—	—	2,000
Hexachloroethane	0.0000	2,000 <sup>g</sup>	—	—	2,000
Indeno(1,2,3-cd)pyrene	0.1585	2,000 <sup>g</sup>	—	—	2,000
Isobutyl alcohol	0.0001	500,000 <sup>g</sup>	—	—	500,000
Isophorone	0.1829	2,000 <sup>g</sup>	—	—	2,000
Isopropyl Alcohol/2-propanol	0.0000	500,000 <sup>g</sup>	—	—	500,000
Kepone	0.2511	—	—	—	—
Mesityl oxide	1.2939	—	—	—	—
Methyl Acetate	0.0057	—	—	—	—
Methylene Chloride	0.0165	2,000 <sup>g</sup>	—	20 <sup>e</sup>	20
Naphthalene	1.9193	2,000 <sup>g</sup>	—	—	2,000
Nitrobenzene	0.0948	100,000 <sup>g</sup>	—	—	100,000
N-Nitroso-di-n-propylamine	0.0035	100,000 <sup>g</sup>	—	—	100,000
N-Nitrosodiphenylamine	0.1896	100,000 <sup>g</sup>	—	—	100,000

Table E-1. (continued).

Constituent <sup>a</sup>	Predicted Concentration in Leachate <sup>b</sup> (mg/L)	Compatible Concentration for HDPE (mg/L)	Compatible Concentration for GCL (mg/L)	Compatible Concentration for Clay (mg/L)	Suggested Maximum Leachate Concentration <sup>c</sup> (mg/L)
Octane,2,3,7-Trimethyl	0.0027	—	—	—	—
o-Toluenesulfonamide	0.0033	—	—	—	—
Pentachlorophenol	0.0046	100,000 <sup>g</sup>	—	—	100,000
Phenanthrene	8.8500	2,000 <sup>g</sup>	—	—	2,000
Phenol	0.1370	100,000 <sup>g</sup>	—	—	100,000
Phenol,2,6-Bis(1,1-Dimethyl)	0.0674	—	—	—	—
p-Toluenesulfonamide	0.0000	—	—	—	—
Pyrene	3.2501	2,000 <sup>g</sup>	—	—	2,000
RDX	0.0000	5,000 <sup>g</sup>	—	—	5,000
Styrene	0.0000	2,000 <sup>g</sup>	—	—	2,000
Tetrachloroethene	0.0235	5,000 <sup>g</sup>	—	20 <sup>h</sup>	20
Toluene	16.3666	—	—	—	—
Tributylphosphate	1.2292	2,000 <sup>g</sup>	—	1,100 <sup>e</sup>	1,100
Trichloroethene	1.1526	—	—	—	—
Trinitrotoluene	0.0000	—	—	—	—
Undecane,4,6-Dimethyl-	0.0003	5,000 <sup>g</sup>	—	—	5,000
Xylene (ortho)	0.0071	—	—	—	—
Xylene (total)	6.2805	—	—	—	—

Notes

a. Constituent reported in the "INEEL CERCLA Disposal Facility Design Inventory (EDF-ER-264)

b. Predicted leachate concentration in the first year of the ICDF landfill operation (EDF-ER-274).

c. The suggested maximum concentration selected for the ICDF liner system is based on the lowest of the concentrations listed for HDPE, GCL, and clay materials and are applicable for the leachate in the landfill and the waste liquids in the evaporation ponds.

d. "—" indicates that a specific test value was not available, compatibility issues are not anticipated.

e. The TCE solubility limit in water is 1,100 mg/l. A minimum of 2 pore volumes of permeant liquid was passed through the clay sample or

f. From "Evaluation of Liner/Leachate Chemical Compatibility for the Environmental Restoration Disposal Facility" (USACE, 1995, *Evaluation* g. From manufacturer specifications.

h. 20 mg/l is the typical concentration of leachate found in municipal landfills. No change in clay permeability was observed at this concentration

i. Maximum allowable concentration reduced by 50 percent since liner may reflect some attack at a pure concentration based on manufacturers maximum concentration data (see Appendix B).

Table E-2. Suggested maximum leachate concentrations for inorganic constituent for liner compatibility.

Constituent <sup>a</sup>	Predicted Concentration in Leachate <sup>b</sup> (mg/L)	Compatible Concentration For HDPE (mg/l)	Compatible Concentration For GCL (mg/l)	Compatible Concentration For Clay (mg/l)	Suggested Maximum Leachate Concentration <sup>c</sup> (mg/l)
Aluminum	28.3029				
Antimony	0.1165				
Arsenic	1.8470	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Barium	3.5848				
Beryllium	0.0011				
Boron	36.4728	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Cadmium	0.5917	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Calcium	4035.0217	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Chloride	31.1061				
Chromium	1.3691				
Cobalt	0.5999	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Copper	1.4906	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Cyanide	4.0932	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Dysprosium	0.2472				
Fluoride	64.4341				
Iron	46.5528				
Lead	0.5753				
Magnesium	883.9838	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Manganese	4.1300				
Mercury	0.0944				
Molybdenum	1.0117	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Nickel	0.1964				
Nitrate	65.4429				
Nitrate/Nitrite-N	3.6979				
Nitrite	0.1414				
Phosphorus	19.2492	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Potassium	74.8819	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Selenium	0.2084	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Silver	0.1092				
Sodium	2.7716				
Strontium	1.5094	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Sulfate	342.1180				
Sulfide	12641.8391				

Table E-2. (continued).

Constituent <sup>a</sup>	Predicted Concentration in Leachate <sup>b</sup> (mg/L)	Compatible Concentration For HDPE (mg/l)	Compatible Concentration For GCL (mg/l)	Compatible Concentration For Clay (mg/l)	Suggested Maximum Leachate Concentration <sup>c</sup> (mg/l)
Terbium	2.3867				
Thallium	0.0037				
Vanadium	3.5063	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Ytterbium	0.8124				
Zinc	12.9486	500,000 <sup>d</sup>	—	— <sup>e</sup>	500,000
Zirconium	0.1151				
Total Inorganic Concentration	18317.5650				

Constituent reported in the "INEEL CERCLA Disposal Facility Design Inventory (EDF-ER-264).

Predicted leachate concentration in the first year of the ICDF landfill operation (EDF-ER-274).

The suggested maximum concentration selected for the ICDF liner system is based on the lowest of the concentrations listed for HDPE, GCL, and clay materials and are applicable for the leachate in the landfill and the waste liquids in the evaporation ponds.

From manufacturer specifications

From manufacturer specifications

Table E-3. Suggested maximum leachate concentrations for radionuclide constituents for liner compatibility in the ICDF Evaporation Pond.

Constituent <sup>a</sup>	Predicted Activity Concentration in Leachate <sup>b</sup> (pCi/L)	Suggested Maximum Activity Concentration <sup>c</sup> (pCi/L)
Ac225	1.1E-07	2.4E+06
Ac227	4.5E-05	1.8E+08
Ac228	3.4E-10	1.0E+07
Ag106	0.0E+00	2.3E+07
Ag108	4.1E-08	—
Ag108m	8.9E+00	8.7E+06
Ag109m	5.5E-11	1.6E+08
Ag110	5.7E-10	1.2E+07
Ag110m	6.2E-08	5.1E+06
Ag111	0.0E+00	—
Am241	7.0E+01	2.6E+06
Am242	1.3E-04	7.4E+07
Am242m	1.3E-04	2.2E+08
Am243	9.8E-04	2.7E+06
Am245	0.0E+00	—
Am246	4.1E-25	1.1E+07
At217	8.5E-04	2.0E+06
Ba136m	0.0E+00	—
Ba137m	4.6E+05	2.1E+07
Ba140	0.0E+00	—
Be 10	4.6E-06	7.0E+07
Bi210	1.1E-05	3.7E+07
Bi211	1.8E-04	2.2E+06
Bi212	5.5E-03	5.0E+06
Bi213	0.0E+00	—
Bi214	5.6E-05	6.6E+06
Bk249	5.4E-22	4.3E+08
Bk250	1.9E-26	1.2E+07
C14	9.1E-03	2.9E+08
Cd109	8.1E-10	7.2E+08
Cd113m	2.7E+02	7.7E+07
Cd115m	7.0E-52	2.3E+07
Ce141	3.6E-71	5.8E+07
Ce142	0.0E+00	—
Ce144	3.6E-03	1.3E+08
Cf249	8.1E-16	2.3E+06
Cf250	4.1E-16	2.4E+06
Cf251	1.9E-18	2.4E+06
Cf252	4.4E-20	1.4E+09

Table E-3. (continued).

Constituent <sup>a</sup>	Predicted Activity Concentration in Leachate <sup>b</sup> (pCi/L)	Suggested Maximum Activity Concentration <sup>c</sup> (pCi/L)
Cm241	3.2E-81	8.3E+07
Cm242	1.3E-17	2.3E+06
Cm243	8.9E-07	2.3E+06
Cm244	4.5E-04	2.4E+06
Cm245	2.0E-08	2.6E+06
Cm246	4.5E-10	2.6E+06
Cm247	1.6E-16	2.7E+06
Cm248	4.9E-17	3.1E+06
Cm250	1.4E-25	1.1E+07
Co57	3.7E-01	9.9E+07
Co58	5.8E-15	1.5E+07
Co60	1.9E+04	5.5E+06
Cr51	7.7E-53	3.9E+08
Cs132	0.0E+00	—
Cs134	2.2E+01	8.3E+06
Cs135	7.2E-02	2.5E+08
Cs136	0.0E+00	—
Cs137	4.9E+04	8.3E+07
Er169	0.0E+00	—
Eu150	5.1E-08	4.9E+07
Eu152	2.8E+03	1.1E+07
Eu154	2.4E+03	9.3E+06
Eu155	5.2E+02	1.2E+08
Eu156	0.0E+00	—
Fe59	2.0E-34	1.1E+07
Fr221	1.0E-07	2.2E+06
Fr223	5.6E-07	3.3E+07
Gd152	1.1E-13	6.6E+06
Gd153	8.4E-11	9.3E+07
H3	8.3E+05	2.5E+09
Hf181	1.7E-36	1.9E+07
Ho166m	1.1E-05	8.2E+06
I129	2.2E+04	1.8E+08
I131	0.0E+00	—
In114	4.8E-54	1.8E+07
In114m	5.1E-54	5.9E+07
In115	1.5E-11	9.3E+07
In115m	0.0E+00	—
K40	1.3E+02	2.3E+07
Kr81 <sup>d</sup>	8.8E-05	—
Kr85 <sup>d</sup>	1.9E+07	-

Table E-3. (continued).

Constituent <sup>a</sup>	Predicted Activity Concentration in Leachate <sup>b</sup> (pCi/L)	Suggested Maximum Activity Concentration <sup>c</sup> (pCi/L)
La138	0.0E+00	—
La140	2.2E-105	5.0E+06
Mn-54	3.9E-07	1.7E+07
Nb92	6.3E-18	9.4E+06
Nb93m	1.3E-01	4.7E+08
Nb94	8.8E-05	8.3E+06
Nb95	4.8E-32	1.8E+07
Nb95m	1.8E-34	5.8E+07
Nd144	1.4E-09	7.5E+06
Nd147	0.0E+00	—
Np235	8.4E-09	1.4E+09
Np236	8.6E-06	4.2E+07
Np237	8.0E+01	2.9E+06
Np238	2.7E-05	1.8E+07
Np239	4.1E-02	3.4E+07
Np240	3.5E-12	8.9E+06
Np240m	3.1E-09	1.5E+07
Pa231	1.3E-04	2.6E+06
Pa233	7.9E-02	3.5E+07
Pa234	5.0E-06	5.8E+06
Pa234m	3.1E-03	1.7E+07
Pb209	4.8E-07	7.2E+07
Pb210	1.1E-05	3.7E+08
Pb211	1.8E-04	2.8E+07
Pb212	5.5E-03	4.4E+07
Pb214	5.6E-05	2.6E+07
Pd107	1.1E-01	4.3E+08
Pm146	2.4E-02	1.7E+07
Pm147	1.6E+03	2.3E+08
Pm148	1.7E-58	1.1E+07
Pm148m	3.4E-57	6.6E+06
Po210	6.8E-06	2.7E+06
Po211	4.6E-09	1.9E+06
Po212	2.2E-03	1.6E+06
Po213	2.9E-07	1.7E+06
Po214	3.7E-05	1.8E+06
Po215	1.2E-04	1.9E+06
Po216	3.7E-03	2.1E+06
Po218	3.7E-05	2.4E+06
Pr143	0.0E+00	—
Pr144	7.4E-03	1.1E+07

Table E-3. (continued).

Constituent <sup>a</sup>	Predicted Activity Concentration in Leachate <sup>b</sup> (pCi/L)	Suggested Maximum Activity Concentration <sup>c</sup> (pCi/L)
Pr144m	1.1E-04	1.2E+09
Pu236	3.9E-05	2.5E+06
Pu237	8.6E-58	2.3E+08
Pu238	1.7E+03	2.6E+06
Pu239	4.8E+01	2.8E+06
Pu240	1.1E+01	2.8E+06
Pu241	4.6E+02	2.7E+09
Pu242	1.7E-03	2.9E+06
Pu243	4.6E-15	7.3E+07
Pu244	1.8E-10	3.1E+06
Pu246	9.9E-25	9.2E+07
Ra222	1.2E-115	2.2E+06
Ra223	2.0E-04	2.4E+06
Ra224	5.5E-03	2.5E+06
Ra225	5.1E-07	1.2E+08
Ra226	4.7E+00	3.0E+06
Ra228	1.5E-09	1.2E+09
Rb86	0.0E+00	—
Rb87	2.0E-04	1.8E+08
Rh102	5.7E-04	1.8E+08
Rh103m	5.4E-57	3.7E+08
Rh106	2.2E-01	8.8E+06
Rn218	2.1E-112	2.0E+06
Rn219	3.4E-01	2.1E+06
Rn220	9.2E+00	2.3E+06
Rn222	1.0E-01	2.6E+06
Ru103	3.6E-28	2.6E+07
Ru106	2.2E-01	3.6E+08
Sb124	4.1E-39	6.3E+06
Sb125	1.9E+02	2.7E+07
Sb126	4.1E-01	4.7E+06
Sb126m	2.9E+00	6.6E+06
Sc46	9.2E-20	6.7E+06
Se79	4.1E+01	2.7E+08
Sm146	1.8E-09	5.6E+06
Sm147	1.7E-05	6.3E+06
Sm148	4.2E-12	7.1E+06
Sm149 <sup>e</sup>	2.1E-11	—
Sm151	1.4E+03	7.2E+08
Sn117m	0.0E+00	—
Sn119m	1.1E-06	7.2E+08

Table E-3. (continued).

Constituent <sup>a</sup>	Predicted Activity Concentration in Leachate <sup>b</sup> (pCi/L)	Suggested Maximum Activity Concentration <sup>c</sup> (pCi/L)
Sn121m	2.1E-01	1.6E+08
Sn123	6.5E-16	4.7E+09
Sn125	0.0E+00	—
Sn126	1.1E+00	2.7E+07
Sr89	5.0E-42	4.0E+07
Sr90	1.9E+06	2.4E+07
Tb160	1.3E-33	2.6E+07
Tb161	0.0E+00	—
Tc 98	6.8E-04	1.1E+07
Tc 99	2.2E+04	9.4E+06
Te123	3.6E-14	1.7E+08
Te123m	2.4E-22	8.3E+08
Te125m	1.8E+01	5.8E+07
Te127	7.5E-19	8.9E+07
Te127m	7.6E-19	6.2E+07
Te129	5.4E-70	1.6E+08
Te129m	8.6E-70	2.4E+07
Th226	2.2E-116	4.6E+07
Th227	1.8E-04	2.2E+06
Th228	3.3E-01	2.3E+06
Th229	5.1E-07	2.6E+06
Th230	1.7E+00	2.8E+06
Th231	1.6E+00	3.0E+06
Th232	1.6E+00	8.0E+07
Th234	1.7E-02	3.5E+06
Tl207	1.8E-04	2.1E+08
Tl208	2.0E-03	2.9E+07
Tl209	1.1E-08	3.6E+06
Tm170	2.7E-25	3.6E+06
Tm171	6.6E-12	4.2E+07
U230	0.0E+00	—
U232	8.8E-02	5.4E+08
U233	4.2E-03	2.7E+06
U234	9.9E+02	2.9E+06
U235	1.8E+01	3.0E+06
U236	3.3E+01	3.1E+06
U237	0.0E+00	—
U238	3.2E+02	3.2E+06
U240	4.2E-09	3.4E+06
Xe127	2.6E-68	8.9E+07
Xe129m	0.0E+00	—

Table E-3. (continued).

Constituent <sup>a</sup>	Predicted Activity Concentration in Leachate <sup>b</sup> (pCi/L)	Suggested Maximum Activity Concentration <sup>c</sup> (pCi/L)
Xe131m	4.5E-108	4.6E+07
Xe133	0.0E+00	—
Y90	1.3E+05	8.8E+07
Y91	2.4E-36	1.5E+07
Zn65	1.7E-07	2.3E+07
Zr93	1.4E+00	2.4E+07
Zr95	4.9E-25	7.3E+08

Notes:

- a. Constituent reported in the "INEEL CERCLA Disposal Facility Design Inventory" (EDF-ER-264).
- b. Predicted average leachate activity concentration during the 15 year operational period.
- c. The suggested maximum activity concentration selected for the ICDF liner system is based on a total absorbed dose of 1,000,000 rads for the individual constituent and a 36 cm liquid waste depth.
- d. The constituents are gaseous elements so not part of the leachate.
- e. Stable isotope

## **Appendix F**

### **Analysis of Leachate Impact on the Liner Systems for the ICDF Landfill and Evaporation Pond**

431.02  
01/30/2003  
Rev. 11

**ENGINEERING DESIGN FILE**

EDF-ER-278  
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TECHNICAL MEMORANDUM

CH2MHILL

# Analysis of Ni-59, Ni-63, and Fe-55 Leachate on the Liner Systems for the ICDF Landfill and Evaporation Ponds

PREPARED FOR: ICDF Implementation Project

PREPARED BY: CH2M HILL

DATE: November 17, 2003

The purpose of this technical memorandum is to evaluate the impact that the leachate will have on the ICDF liner systems based on the addition Ni-59, Ni-63, and Fe-55 to the waste inventory at the INEEL CERCLA Disposal Facility (ICDF).

## Requirements

For the given soil concentrations, the estimated concentrations of the identified radionuclides in the leachate during the fifteen-year operations period and the effect on the liner system will be evaluated.

## Background

The INEEL plans to dispose of remediation wastes at the INEEL CERCLA Disposal Facility (ICDF). Recent evaluations identified three radionuclides which had not been included in the original design inventory. As such, these radionuclides were not assigned WAC guideline concentrations or mass limits. These radionuclides are Nickel-59 (Ni-59), Nickel-63 (Ni-63), and Iron-55 (Fe-55).

## Methodology

This evaluation involves calculating estimated leachate concentrations for each radionuclide listed above according to the methodologies presented in EDF-ER-274.

## Calculation of Leachate Concentrations

Leachate and mass reduction estimates for these constituents were evaluated by adding the constituents to the spreadsheet used in EDF-ER-274, determining contaminant distribution coefficients (Kds) consistent with EDF-ER-274 methodology and performing leachate concentration and mass reduction calculations. The radionuclides are assigned the same Kd values as were originally assigned to the non-isotopic, total metal elemental forms (100 ml/g for Ni and 220 ml/g for Fe). Leachate concentrations and mass exiting the waste soil are calculated for each radionuclide over the simulation period of 15 years and are adjusted for radiological decay.

### Calculation of Radiation Dose

The radiation dose from the three radionuclides was determined utilizing the methods described in EDF-ER-278. The average leachate concentration for the radionuclides evaluated in this memo were added to a radiation dosage spreadsheets as shown in EDF-ER-278, Appendix B. These spreadsheets calculate the maximum dosage that each constituent would contribute to the landfill and evaporation pond liners.

## Results and Discussion

### Leachate Concentrations

Table 1 shows the results of the leachate concentration calculations.

**TABLE 1**  
Input Parameters and Peak Leachate Concentration for Ni-59, Ni-63, and Fe-55 at Measured Soil Concentrations.

Constituent	New Soil Concentration (pCi/kg) <sup>1</sup>	Kd surrogate bin <sup>2</sup>	Half-Life (yrs) <sup>3</sup>	Peak Leachate Concentration (pCi/L)	Peak Leachate Concentration (mg/L)
Ni-59	9.50E+06	7	7.60E+04	9.49E+04	1.17E-03
Ni-63	6.00E+07	7	1.00E+02	6.00E+05	1.30E-05
Fe-55	2.00E+09	7	2.70E+00	9.09E+06	4.13E-06

<sup>1</sup>Soil Concentration provided via e-mail originating from Jim Curnutt on 8/27/03.

<sup>2</sup>As reported in EDF-ER-275.

<sup>3</sup> "Table of Nuclides (c) 2000-2002 Nuclear Data Evaluation Lab. Korea Atomic Energy Research Institute <http://www2.bnl.gov/ton/index.html>".

### Radiation Doses

Table 2 shows the results of the radiation dose calculations, based on the previously described spreadsheet model.

**TABLE 2**

Constituent	Landfill Dose (Rads/hr)	Evaporation Pond Dose (Rads/hr)
Ni-59	3.80E-05	3.42E-04
Ni-63	5.78E-04	5.21E-03
Fe-55	7.98E-04	7.18E-03
Total	1.41E-03	1.27E-02

Based on these results, the landfill and evaporation pond liners will be exposed to a maximum total quantity of radiation over a 15-year period of 185 rads (1.41E-03 rads/hr over 15 years), and 1,669 rads (1.27E-02 rads/hr over 15 years), respectively.

### Liner Compatibility

As described in EDF-278, individual constituents in the ICDF landfill design inventory were evaluated to determine maximum allowable ICDF landfill waste concentrations, that if placed in the landfill would generate leachate compatible with the liner system. Many of the individual design inventory constituents have not been included in the composition of leachate used for published compatibility studies. However, the constituents used in the published studies are in similar chemical groups as the constituents in the ICDF design inventory and therefore, would react similarly with the liner materials. Moreover, the use of general chemical categories rather than individual constituents provide a worst-case scenario due to possible synergistic effects of mixed compounds.

Table 3 provides the recommended maximum concentration of chemical categories that, if present in the landfill leachate, may be incompatible with the polymeric or earthen material comprising the ICDF landfill and evaporation pond liner systems. These limits are based on review of the published liner compatibility studies and manufacturers' recommendations. The maximum allowable concentration for HDPE geomembrane, GCL, and SBL were compared to determine the highest acceptable value. The lowest of all three values was selected as the suggested maximum concentration.

TABLE 3

Chemical Category	Compatible Concentration for HDPE	Compatible Concentration for GCL and Clay	Suggested ICDF Maximum Concentration or Value	Design Inventory Concentration Dose or Value
Organics	500,000 <sup>a</sup> mg/L	500,000 <sup>b</sup> mg/L	500,000 mg/L	70 mg/L
Acids and Bases	750,000 <sup>a</sup> mg/L	500,000 <sup>b</sup> mg/L	500,000 mg/L	0 <sup>d</sup> mg/L
Inorganics	500,000 <sup>a</sup> mg/L	500,000 <sup>b</sup> mg/L	500,000 mg/L	17,100 mg/L
Dissolved Salts	No Limit	35,000 mg/L	35,000 mg/L	8,000 mg/L <sup>c</sup>
Strong Oxidizers	1,000 mg/L	No limit	1,000 mg/L	0 <sup>d</sup> mg/L
Radionuclides	1,000,000 <sup>b</sup> rads	No limit	1,000,000 rads	12,000 rads (15 yr) 800,000 rads (1000 yr)
pH	0.5 - 13.0 <sup>a</sup>	0.5 - 13.0	0.5 - 13.0	8.0

a. Based on the manufacturers' maximum concentration of the list of constituents tested by the manufacturers. The manufacturers' recommendations are provided in Appendix C of EDF-ER-278.  
b. Based on reported literature values.  
c. Based on the maximum sodium concentration determined in the Geochemical Evaluation.  
d. Strong acids, bases, or oxidizing compounds were not reported in the design inventory.

### Conclusions

Comparing the information in Table 3 and the aforementioned concentration and radiation dose calculations show the following:

1. The total dose applied to the landfill and evaporation pond liners will only slightly increase the total radiation dose over the life of the facility, and will not approach the recommended limit of 1,000,000 rads. Therefore, the addition of the radionuclides to the waste inventory will not negatively affect the integrity of the liner systems.
2. EDF-ER-278 should be amended to include the results of this memo.

## **References**

EDF-ER-274, 2002, "Leachate Contaminant Reduction Time Study", Rev 1., Environmental Restoration Program, Idaho National Engineering and Environmental Laboratory, 2002.

EDF-ER-278, 2002, "Liner/Leachate Compatibility Study", Rev 1., Environmental Restoration Program, Idaho National Engineering and Environmental Laboratory, 2002.

DOE-ID, 2003, *Waste Acceptance Criteria for ICDF Landfill*, DOE/ID-10865, Rev.3, U.S. Department of Energy Idaho Operations Office, Idaho Falls, Idaho, July 2003.

TECHNICAL MEMORANDUM

CH2MHILL

## Analysis of Leachate Impact on the Liner Systems for the ICDF Landfill and Evaporation Ponds

PREPARED FOR: ICDF Implementation Project

PREPARED BY: CH2M HILL

DATE: March 24, 2004

The purpose of this technical memorandum is to evaluate the impact that the leachate will have on the ICDF liner systems based on addition of several constituents to the waste inventory at the INEEL CERCLA Disposal Facility (ICDF). The analysis also accounts for increasing the soil concentration of several constituents that were included in the original design inventory.

### Requirements

Determine the impact on the liner system for the estimated leachate concentrations of the identified constituents during the fifteen-year operations period.

### Background

The INEEL plans to dispose of remediation wastes at the ICDF. Recent evaluations identified constituents which had not been included in the original design inventory or were included in the original design inventory but are included in this analysis because it has been found that the soil concentration of each constituent is significantly greater than that of the original design inventory. As such, these constituents were not assigned WAC guideline concentrations or mass limits, or these limits have been revised due to the increased soil concentration. The list of constituents can be found in Table 2.

### Methodology

This evaluation compares estimated leachate concentrations of each constituent to known concentration limits for the liner system in accordance with EDF-ER-278, "Liner/Leachate Compatibility Study".

### Results and Discussion

#### Liner Compatibility

As described in EDF-278, "Liner/Leachate Compatibility Study", individual constituents in the ICDF landfill design inventory were evaluated to determine maximum allowable ICDF landfill waste concentrations, that if placed in the landfill would generate leachate compatible with the liner system. Many of the individual design inventory constituents have not been included in the composition of leachate used for published compatibility studies. However, the constituents used in the published studies are in similar chemical groups as the constituents in the ICDF design inventory and therefore, would react similarly

with the liner materials. Moreover, the use of general chemical categories rather than individual constituents provide a worst-case scenario due to possible synergistic effects of mixed compounds.

Table 1 provides the recommended maximum concentration of chemical categories that, if present in the landfill leachate, may be incompatible with the polymeric or earthen material comprising the ICDF landfill and evaporation pond liner systems. These limits are based on review of the published liner compatibility studies and manufacturers' recommendations. The maximum allowable concentration for HDPE (high density polyethylene) geomembrane, GCL (geosynthetic clay liner), and SBL (sodium bentonite liner) were compared to determine the highest acceptable value. The lowest of all three values was selected as the suggested maximum concentration.

TABLE 1

Chemical Category	Compatible Concentration for HDPE	Compatible Concentration for GCL and SBL	Suggested ICDF Maximum Concentration or Value	New Design Inventory Concentration Dose or Value
Organics	500,000 <sup>a</sup> mg/L	500,000 <sup>b</sup> mg/L	500,000 mg/L	58,000 mg/L <sup>e</sup>
Acids and Bases	750,000 <sup>a</sup> mg/L	500,000 <sup>b</sup> mg/L	500,000 mg/L	0 <sup>d</sup> mg/L
Inorganics	500,000 <sup>a</sup> mg/L	500,000 <sup>b</sup> mg/L	500,000 mg/L	280,000 mg/L <sup>e</sup>
Dissolved Salts	No Limit	35,000 mg/L	35,000 mg/L	8,000 mg/L <sup>c</sup>
Strong Oxidizers	1,000 mg/L	No limit	1,000 mg/L	0 <sup>d</sup> mg/L
Radionuclides	1,000,000 <sup>b</sup> rads	No limit	1,000,000 rads	13,400 rads (15 yr) 895,000 rads (1000 yr)
pH	0.5 - 13.0 <sup>a</sup>	0.5 - 13.0	0.5 - 13.0	8.0

- a. Based on the manufacturers' maximum concentration of the list of constituents tested by the manufacturers. The manufacturers' recommendations are provided in Appendix C of EDF-ER-278.
- b. Based on reported literature values as discussed in EDF-ER-278.
- c. Based on the maximum sodium concentration determined in the Geochemical Evaluation.
- d. Strong acids, bases, or oxidizing compounds were not reported in the design inventory.
- e. Total organic and inorganic concentrations increased significantly above the previous estimate. This is due to assuming that all soil placed in the ICDF landfill contains the organic and inorganic constituents at the design inventory concentrations. In actuality, only a fraction of the soil will contain these constituents at the design inventory concentrations.

The results of the liner compatibility analysis can be found in Table 2.

**TABLE 2**

Constituents	Average Leachate Concentration [C <sub>Liquid</sub> ] <sup>a</sup> (mg/L or pCi/L)	Design Inventory Concentration in Soil [C <sub>Soil</sub> ] <sup>b</sup> (mg/kg or pCi/kg)	Soil Concentration to Average Leachate Concentration Ratio [C <sub>Soil</sub> /C <sub>Liquid</sub> ] (L/kg)	Maximum Concentration Allowed in Leachate For Compatibility [C <sub>Leachate</sub> ] <sup>c</sup> (mg/L or pCi/L)	Maximum Allowable Concentration in Soil For Compatibility (mg/kg or pCi/kg)
<b>INORGANICS</b>					
Bromide	5.4E+01	3.6E+00	6.6E-02	5.0E+05	3.3E+04
Phosphate	8.6E+01	5.7E+00	6.6E-02	5.0E+05	3.3E+04
Silicon	2.4E+05	1.6E+04	6.6E-02	5.0E+05	3.3E+04
Tin	3.0E+01	3.0E+00	1.0E-01	5.0E+05	5.1E+04
<b>ORGANICS</b>					
1,2,3,4,6,7,8,9-OCDD	2.7E-04	6.9E-02	2.5E+02	5.0E+05	1.3E+08
1,2,3,4,6,7,8,9-OCDF	5.7E-05	1.4E-02	2.5E+02	5.0E+05	1.3E+08
1,2,3,4,6,7,8-HxCDD	1.8E-04	4.6E-02	2.5E+02	5.0E+05	1.3E+08
1,2,3,4,6,7,8-HxCDF	4.8E-04	1.2E-01	2.5E+02	5.0E+05	1.3E+08
1,2,3,4,7,8,9-HxCDF	2.3E-06	5.9E-04	2.5E+02	5.0E+05	1.3E+08
1,2,3,4,7,8-HxCDD	4.4E-07	1.1E-04	2.5E+02	5.0E+05	1.3E+08
1,2,3,4,7,8-HxCDF	7.8E-04	2.0E-01	2.5E+02	5.0E+05	1.3E+08
1,2,3,6,7,8-HxCDD	3.3E-06	8.4E-04	2.5E+02	5.0E+05	1.3E+08
1,2,3,6,7,8-HxCDF	4.0E-05	1.0E-02	2.5E+02	5.0E+05	1.3E+08
1,2,3,7,8,9-HxCDD	9.4E-06	2.4E-03	2.5E+02	5.0E+05	1.3E+08
1,2,3,7,8,9-HxCDF	8.8E-08	2.2E-05	2.5E+02	5.0E+05	1.3E+08
1,2,3,7,8-PeCDD	4.2E-07	1.1E-04	2.5E+02	5.0E+05	1.3E+08
1,2,3,7,8-PeCDF	3.7E-06	9.3E-04	2.5E+02	5.0E+05	1.3E+08
2,3,4,6,7,8-HxCDF	6.5E-05	1.6E-02	2.5E+02	5.0E+05	1.3E+08
2,3,4,7,8-PeCDF	2.5E-05	6.3E-03	2.5E+02	5.0E+05	1.3E+08
2,3,7,8-TCDD	1.6E-08	4.1E-06	2.5E+02	5.0E+05	1.3E+08
2,3,7,8-TCDF	2.2E-04	5.5E-02	2.5E+02	5.0E+05	1.3E+08
1,2-dichloroethane	3.5E+01	2.5E+01	7.1E-01	2.0E+03	1.4E+03
2-nitroaniline	2.1E+01	3.4E+00	1.6E-01	5.0E+05	8.2E+04
3-nitroaniline	2.1E+00	3.4E+00	1.6E+00	5.0E+05	8.2E+05
4-nitroaniline	2.1E+01	3.4E+00	1.6E-01	5.0E+05	8.2E+04
Aroclor-1262	3.7E-03	5.0E+00	1.3E+03	2.0E+03	2.6E+06

**TABLE 2**

Constituents	Average Leachate Concentration [C <sub>Liquid</sub> ] <sup>a</sup> (mg/L or pCi/L)	Design Inventory Concentration in Soil [C <sub>Soil</sub> ] <sup>b</sup> (mg/kg or pCi/kg)	Soil Concentration to Average Leachate Concentration Ratio [C <sub>Soil</sub> /C <sub>Liquid</sub> ] (L/kg)	Maximum Concentration Allowed in Leachate For Compatibility [C <sub>Leachate</sub> ] <sup>c</sup> (mg/L or pCi/L)	Maximum Allowable Concentration in Soil For Compatibility (mg/kg or pCi/kg)
Bromomethane	3.9E+01	4.0E+00	1.0E-01	5.0E+05	5.1E+04
Polyvinyl Chloride	2.7E+00	2.7E+03	1.0E+03	5.0E+05	5.0E+08
Styrene	5.8E+04	4.3E+04	7.3E-01	2.0E+03	1.5E+03
Vinyl Chloride	9.7E+01	1.2E+01	1.3E-01	2.0E+03	2.5E+02
<b>RADIONUCLIDES</b>					
U233	2.7E+04	1.6E+05	6.1E+00	2.7E+07	1.6E+08

a. As determined from EDF-ER-274, "Leachate Contaminant Reduction Time Study".  
 b. As provided by BBWI in CN-23 dated February 3, 2004.  
 c. Determined from manufacturers' literature as given in EDF-ER-278, "Liner/Leachate Compatibility Study", Appendix C (See Table 1).

Comparison of the maximum allowable concentration in soil for compatibility to the design inventory concentration in soil from Table 1 for each constituent leads to the following conclusion:

1. None of the constituents, with the exception of styrene, has a design inventory soil concentration that will produce a leachate concentration that exceeds the maximum allowed concentration for compatibility.
2. The concentration of styrene in the leachate is a conservative estimate that is based on all soil placed in the ICDF landfill containing styrene at the design inventory concentration. In actuality, only a fraction of the soil will contain styrene at this concentration.

## Conclusions

This analysis was used to determine impacts to the liner compatibility. EDF-ER-278 should be amended to include the results of this memo.

## References

EDF-ER-274, 2002, "Leachate Contaminant Reduction Time Study", Rev 1., Environmental Restoration Program, Idaho National Engineering and Environmental Laboratory, 2002.

EDF-ER-278, 2002, "Liner/Leachate Compatibility Study", Rev 1., Environmental Restoration Program, Idaho National Engineering and Environmental Laboratory, 2002.